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ON THE STRENGTH, ELASTICITY, DUCTILITY, AND RESILIENCE OF MATERIALS OF MACHINE CONSTRUCTION, AND ON VARIOUS HITHERTO UNOBSERVED PHENOMENA, NOTICED DURING EXPERIMENTAL RESEARCHES WITH A NEW TESTING MACHINE, FITTED WITH AN AUTOGRAPHIC REGISTRY.*

A paper by Prof. R. H. Thurston, Member of the American Society of Civil Engineers, read February 4th, 1874.

SECTION I.

1. *Introductory.*—Some months ago,† while engaged with the advanced classes of the Stevens Institute of Technology, in experimental investigations of the resistance of materials, it was found that coefficients were given, by various authorities, which neither accorded fully with each other nor with those then obtained.

The desirability of determining how far these differences were due to errors of observation, and how far to variation in the quality of the materials examined, induced the writer to design several machines for the purpose of conducting with them a more extended and exact series of experiments. The machine for measuring torsional resistance was furnished with an automatic registry, recording a diagram which is a reliable and exact representation of all circumstances attending the distortion and fracture of the specimen. No system of personal observation could probably be devised which could yield results either as reliable or as precise as such a system of autographic registry, and, as no method previously in use had given simultaneously, and at every instant during the test, the intensity of the distorting force and the magnitude of the coincident distortion, it was anticipated that the new method of investigation might be fruitful of new and, possibly, important results. This expectation, as will be seen, has been more than realized.

2. *Description of the Apparatus.*—The machine, as planned by the writer, and as built in the instrument maker's workshop at the Stevens Institute, is shown in Fig. 1. This form is that with which the investigations to be described were made. Since its construction, in 1872, however, some changes and improvements have been made in the design to adapt it to general work, and new designs have been made for special kinds of work, as for wire mills, railroad shops, and bridge building.

Two strong wrenches, C E, B D, are carried by the frames A A, A^1 A^1, and depend from axes which are both in the same line but are not connected with each other. The arm, B, of one of these wrenches carries a weight, D, at its lower end. The other arm, C, is designed to be moved by hand, in the smaller machines, and by a gear and pinion, or a worm gear in larger forms of the apparatus. The heads of the wrenches are made as shown in Fig. 2, the recess, M, being fitted to take

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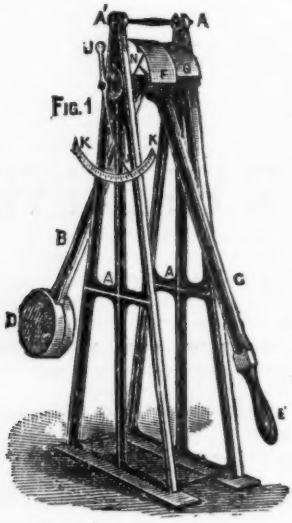
† *Vide* Journal Franklin Institute, 1873.

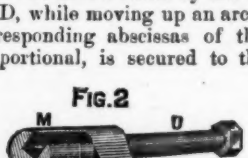
the head, on the end of the test pieces, which is usually given the form shown in Fig. 4.

FIG. 1



A guide curve, F, of such form that its ordinates are precisely proportional to the torsional moments exerted by the weighted arm, B D, while moving up an arc to which the corresponding abscissas of the curve are proportional, is secured to the frame

FIG. 2

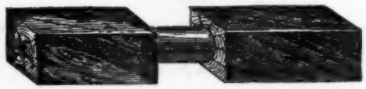


A A^1. The pencil holder, J, is carried on this arm, B D, and as the latter is forced out of the vertical position, the pencil is pushed forward by the guide curve, its movement being thus made proportionate to the force which, transmitted through the

FIG. 3

test piece, produces deflection of the weighted arm. This guide line is a curve of sines. The other arm, C E, carries the cylinder, G, upon which the paper receiving the record is clamped, and the pencil, J, makes its mark on the table thus provided. This table having a motion, relatively to the pencil, which is precisely the angular relative motion of the two extremities of the tested specimen, the curve described upon the paper is always of such form that the ordinate of any point measures the amount

FIG. 4



of the distorting force at a certain instant, while its abscissa measures the distortion produced at the same instant. The maximum hand, J, is sometimes useful as a check upon the record of maximum resistance.

The convenience of operation, the small cost,* and the portability of the machine are hardly less important to the engineer than the accuracy, and the extraordinary extent of information obtainable by it.

3. *Method of Operation.*—The test piece having been given the shape and size which are found best suited for the purposes of the experiment, and to the capacity of the machine, it is placed in the jaws of the two wrenches, each of which takes one of its squared ends, and, a force being applied to the handle, E, the strain thrown upon the specimen is transmitted through it to the weighted arm, B D, causing it to swing about its axis until the weight exerts a moment of resistance which equilibrates the applied force. As the magnitude of the distorting force changes, the position of the weight simultaneously changes, and the pencil indicates, at each instant, the value of the stress upon the test piece. As the piece yields under strains of increasing amount, also, the pencil is carried in the direction of the circumference of the cylinder on which its record is made, and to a distance which is proportional to the amount of distortion, *i. e.*, to the "total angle of torsion." As the applied force increases, the specimen yields, and finally, rupture occurring, the pencil returns to the base line, at a distance from the starting point which measures the angle through which the test piece yielded before its fracture became complete.

* Machines of the size of that used in these experiments, but of improved design, are made at the Stevens Institute, at prices as low as $150.

4. *Interpretation of the Diagrams.*—It has been shown that the vertical scale of the diagrams produced is a scale of torsional moments, and that the horizontal scale is one of total angles of torsion. Since the resistance to shearing, in a homogeneous material, varies with the resistance to longitudinal stress, it follows that the vertical scale is also, for such materials, a scale of direct resistance, and that, with approximately homogeneous substances, this scale is approximately accurate, where, as here, all specimens compared are of the same dimensions. Since the elasticity of the material is measured by the ratio of the distorting force to the degree of temporary distortion produced, the diagrams obtained will exhibit the elastic properties of the material, as well as measure its ductility and its resilience.

Referring to the diagrams shown in the accompanying plates, it will be noticed that the first portion of the line is a curve of small radius, convex toward the axis of abscissas, and that the line then rises at a slight inclination from the vertical, but becoming very nearly straight, until, at a point some distance above the origin, it takes a reversed curvature. The first portion of the line is probably formed by the yielding of the loosely fitted packing pieces securing the heads of the specimen, and after they have taken a bearing, by the early yielding, in some materials, of particles already overstrained. When a firm hold is obtained, the line becomes sometimes nearly straight, and the amount of distortion is seen to be approximately proportional to the distorting force, illustrating "Hooke's law," *Ut tensio sic vis.*

After a degree of distortion which is determined by the specific character of each piece, the line becomes curved, the change of form having a rate of increase which varies more rapidly than the applied force. When this change commences, it seems probable that the molecules, which, up to that point, retain generally, their original distribution, while varying their relative distances, begin to change their positions with respect to each other, moving upon each other in a manner similar, probably, to that action described by Mon. Tresca, and called the "Flow of Solids,"* and to which attention has already been called by Prof. J. Thompson.†

It is this point, at which the line commences to become concave toward the base, that is considered to mark the "limit of elasticity." It will be noticed that it is well defined in experiments upon woods, is less marked, but still well defined in the "fibrous" irons and the less homogeneous specimens of other metals, and becomes quite indeterminable with the most homogeneous materials, as with the best qualities of well worked cast-steel. This point does not indicate the first "set," since, as will be hereafter seen, a set is found to occur, either temporary or permanent, and usually partly temporary and partly permanent, with every degree of distortion, however small. It is at this "elastic limit" that the sets begin to become considerable in amount and almost wholly permanent.

The inclination of the straight portion of the line from the vertical measures the stiffness of the specimen, the quantity $Cot.\ \Theta = \frac{1}{\text{Tan. }\Theta}$ being the ratio of the distorting force to the amount of distortion up to the "limit of elasticity." As it would seem from the results of experiment, as well as of deduction, that this rigidity is very closely, if not precisely, proportional to the hardness, in homogeneous substances, this quantity $Cot.\ \Theta$ may be taken, for practical purposes, as a measure of the hardness of the metals, as well as of their elastic resistance to compression.

After passing the elastic limit, the line becomes more and more nearly parallel to the base line, and then, with the woods invariably, and in some cases with the metals, begins to fall rapidly before fracture becomes evident in the specimen. Where the rising portion of the line turns and becomes nearly parallel with the axis of abscissas, the viscosity of the material is such that the outer particles "flow" upon those within, and, while themselves still offering maximum resistance, permit molecules nearer the axis to also resist with approximately maximum force. It seems probable that, with the more ductile substances, nearly all are brought up to a maximum in resistance before fracture occurs, and this circumstance will be seen hereafter to have an important influence in determining the

* L'Ecoulement des Corps Solides. Paris, 1869, 1871.

† Cambridge and Dublin Mathematical Journal, Vol. III., 1848, pp. 252-266.

resistance to rupture. The hardest and most brittle materials break, with a snap, before any such flow becomes perceivable, and before the line of the diagram commences to deviate, in the slightest degree, from the direction taken at the beginning, and before the approach to the elastic limit is indicated. It is evident that the standard formulas for torsional, as well as for other forms of resistance, cannot be perfectly correct, since they do not exhibit this difference in the character of the resistance offered by ductile and by rigid materials.

The elasticity of the material is determined by relaxing the distorting force, at intervals, and allowing the specimen to relieve itself from distortion so far as its elasticity will permit. In such cases, the pencil will be found to have traced a line resembling, in its general form and position, in respect to the coördinates, that forming the initial portion of the diagram, but almost absolutely straight, and more nearly vertical. The degree of inclination of this line indicated the elasticity, precisely as the initial straight line was made to give a measure of the original stiffness of the test piece, the cotangent of the angle made with the vertical, Cot. $\Phi = \frac{\xi^1}{\text{Tan. } \theta}$ being the ratio of the force required to spring the piece through the range recoverable by elasticity, to the magnitude of that range. The fact, to be shown, that this value is always greater than Cot. Φ, for the same metal is evidence that more or less permanent set will always occur, and that the original stiffness of the specimen is always modified, whatever the magnitude of the applied force. The form of the line of elastic change indicates also the character of the molecular action producing it.

Finally, the form of the curve after passing the maximum, or after passing the point at which fracture commences, exhibits the method of variation of strength during the process of fracture. This portion is very difficult to obtain, with even approximate accuracy, with any but the tougbest and most ductile materials. This terminal portion of the diagram would be, theoretically, a cubic parabola, the loss of resisting power varying with the progressive rupture of concentric layers, and the remaining unbroken cylindrical portion becoming smaller and smaller until resistance vanishes with the fracture of the axial line. In some cases, the curves obtained from ductile metals exhibit this parabolic line very distinctly. In all hard materials, the jar produced by the sudden rupture of surface particles is sufficient to separate those within, and the terminal line is straight and vertical.

The homogeneity of the material tested is frequently hardly less important than its strength, and it is very desirable to obtain evidence which may enable the experimenter to determine the value of tests of samples as indicative of the character of the lot from which the specimens may have been taken. If the specimens are found to be perfectly homogeneous, it may be assumed with confidence that they represent accurately the whole lot. If the samples are irregular in structure and in strength, no reliable judgment of the value of the lot can be based upon their character, and there can be no assurance that, among the pieces accepted, there may not be untrustworthy material which may possibly be placed just where it is most important to have the best. It is evident that the more homogeneous a material, the more regularly would changes in its resistance take place, and the smoother and more symmetrical would be the diagram. The depression of the line immediately after passing the elastic limit exhibits the greater or less homogeneousness of the material. The fact is illustrated in a striking manner in some of the curves presented, and we thus have—what had never, I believe, been before found—this method of determining homogeneousness.

The resilience of the specimen is measured by the area includedwithin its curve, this being the product of the mean force exerted into the distance through which it acts in producing rupture, *i. e.*, it is proportional to the work done by the test piece in resisting fracture, and represents the value of the material for resisting shock. The area taken within the ordinate of the limit of elasticity, measures the capacity for resisting shock without serious distortion or injurious set.

The ductility of the specimen is deduced from the value of the total angle of torsion, and the measure is the elongation of a line of surface particles, originally parallel to the axis, which line assumes a helical form as the test piece yields, and finally parts at or near the point where the maximum resistance is formed. Its value is given on Plates II. and III. for each 10 deg. of arc. Since, in this case, there is no appreciable

reduction of section, or change of form, in the specimen, this value of elongation is our actual measure of the maximum ductility of the material, and is an even more accurate indication than the area of fractured cross section as usually measured after rupture by tension. It is to be understood that wherever comparisons are here made, without the express statement of other conditions, specimens of the same dimensions are always represented in the diagrams.

5. *Description of Illustrated Diagrams. The Woods.**—Plates I. and II. exhibit sets of curves which illustrate the general characteristics of a large number of materials, the first showing the peculiarities noted during experiments on the woods, and the second giving an interesting comparison of the metals.

The woods experimented upon were the following, the numbers of the respective curves on Plate I. indicating the material here correspondingly marked:—

1. White pine (*Pinus Strobus*).
2. Southern pine (*Pinus Australis*), sap, wood.
3. Southern pine, heartwood.
4. Black spruce (*Abies Nigra*).
5. Ash (*Fraxinus Americanus*).
6. Black walnut (*Juglans Nigra*).
7. Red cedar (*Juniperus Virginianus*).
8. Spanish mahogany (*Swietenia Mahogani*).
9. White oak (*Quercus Alba*).
10. Hickory (*Carya Alba*).
11. Locust (*Robinia Pseudo-acacia*).
12. Chestnut (*Castanea Vesca*).

The specimens are all of the form shown in Fig. 3, three and three-fourth inches long, with a diameter of neck of seven-eighths of an inch.

It will be noticed that, in all cases, at the commencement of the line, it rises at a slight inclination from the vertical and almost perfectly straight. This confirmation of Hooke's law, within the limit of elasticity, is best shown in the detached portion *a*, *a*, *a*, of the curve obtained with locust, in which the horizontal scale is somewhat magnified. The distortion is seen to be very precisely proportional to the distorting force, until the law changes at the limit of elasticity.

It will be observed that, in the larger number of cases, the torsional resistance increases with great regularity nearly to the angle of maximum stress, where, suddenly, this rapid rate of increase ceases, and the limit of elastic resistance being passed, resistance diminishes rapidly with further increase of angular movement, until it becomes zero. In the tougher and more dense varieties, this decrease of resistance occurs less slowly, and in some cases only disappears after a large angle of torsion is recorded. In the curves of exceptionally strong and tough woods, in which there is known to exist a great excess of longitudinal over lateral cohesion, as in those of black walnut 6, 6, locust 11, 11, and especially in those of hickory 10, 10, a peculiarity is perceivable which is somewhat remarkable, and which is especially important in a connection to be hereafter referred to at length.

In these instances the resistance is proportional to the amount of torsion, until a maximum is reached; the line then falls as torsion continues, until a minimum is passed, the curve then again rising and passing another maximum before finally commencing an unintermitted descent to the axis of abscissas. Where the difference between longitudinal and lateral cohesion is exceptionally great, the second maximum may, as illustrated, for example, by the line described in recording the test of hickory, have a higher value even than the first. This interesting and previously unanticipated peculiarity was shown, by careful observation, to be due to the sudden yielding of lateral cohesion when the torsional moment reached the value indicated by the first minimum. The fibres being thus loosened from each other, this loose bundle of filaments yielded readily, until, by lateral crowding as they assumed a helical form and enwrapped each other, their slipping upon each other was gradually checked, and resistance again commenced increasing. At the second maximum, yielding again began in consequence of the breaking of fibres under the longitudinal stress measured by that component of torsional force having a direction parallel with the filaments in their new positions, the exterior surface threads parting first under this tensile stress, and rupture progressing by the yielding of layer after layer, until, the axial line being reached, resistance vanished. In this case, rupture seems never to occur by true shearing along

* A portion of this section has appeared in an earlier number of this magazine. It is here retained in order that this paper may be preserved complete, and in order that the comparison between strain-diagrams of woods and metals may be readily made.

one defined transverse plane. This feature of depression in the curve, occurring as described, is therefore the indication of a lack of symmetry in the distribution of resisting forces. It is evident that it may occur either by a difference in the value of cohesive force in the lateral and longitudinal directions or by the structural defects of a specimen in which the substance itself may be endowed with cohesion of equal intensity in all directions.

The curves shown in Plate I. exhibit well the relative values of these materials for the various purposes of the engineer.

White pine, 1, 1, 1, is shown by the considerable inclination of the line of stiffness from the vertical, to be soft and deficient in rigidity. The limit of elasticity is quickly reached, and the maximum resistance of the specimen is found at 15½ foot-pounds of moment. Rapidly losing strength after passing the limit of resistance, it is entirely broken off at an angle of 130 deg. The small area comprised by the diagram proves its deficiency of resistance, and its inability to sustain shock.

Yellow pine, 2, 2, 2, 3, 3, 3, far excels the first in all valuable properties shown by the curve. The sapwood seems, in the specimens tested, equally stiff with the heart, but it reaches the elastic limit sooner. The general form of the diagram is the same in both, and is characteristically different from that of the white pine. It evidently has great value wherever rigidity, strength, toughness, and resilience are desired in combination with lightness, the latter most important quality, together with their cheapness, aiding the qualities here shown in determining the application of these woods so extensively for general purposes. It should be noted that, since all comparisons of strength are based on measures of volume, a comparison of densities should usually be obtained to assist the judgment in making a choice from among materials of which tests have been made.

Spruce, 4, 4, 4, while possessing far less stiffness than even white pine, excels it somewhat in strength, passing its maximum at 18 foot-pounds, and submitting to a torsion of nearly 200 deg. It is proven to possess proportionally greater resilience also. It is, however, far inferior to the yellow pine in every respect.

Ash, 5, 5, 5, is more deficient in strength and toughness than is generally supposed, and rapidly loses its power of resistance after passing the maximum, which point is found at about 27½ foot-pounds. These specimens may have been of exceptionably poor quality, or, possibly, were over-seasoned.

Black walnut, 6, 6, 6, is remarkably stiff; strong, and resilient, its diagram resembling somewhat that of oak in general form and dimensions. The maximum of resistance reaches 35 foot-pounds, and the most ductile specimen was only broken off after yielding through an arc of 220 deg. Its stiffness is shown by the fact that it required a moment of 25 foot-pounds to spring it 10 deg., yellow pine requiring but 22 foot-pounds and spruce but 8 to give them the same amount of distortion.

Red cedar, 7, 7, 7, is very stiff, but is brittle and deficient in strength, breaking off at 92 deg., and having a maximum power of resistance of but 20½ foot-pounds. It is, however, one of the stiffest of the woods, its specimen requiring 20 foot-pounds of torsional moment to produce a total angle of torsion of but 5 deg.

Spanish mahogany, 8, 8, 8, is both strong and stiff, bearing a stress of 44 foot-pounds, and requiring 32 to produce a torsion of 10 deg.

White oak, 9, 9, 9, exhibits less strength than either good mahogany, locust, or hickory, but it is exceedingly tough and resilient. Passing the maximum at an angle of 15 deg., under a torsional stress of 35½ foot-pounds, it retains its power of resistance nearly unimpaired up to about 70 deg., and then slowly yields until it suddenly gives way, after passing the angle 250 deg., under a strain due to 9 foot-pounds, and breaks off completely at 253 deg. This strength, toughness, and endurance, under strains due to impact, may be attributed to its considerable lateral cohesion, and to the interlacing of its tenacious fibres, which gives this wood its "cross" grain.

Hickory, 10, 10, 10, has the highest maximum found during these experiments, the second of the pair of maxima already referred to being considerably above the maximum of locust, even. This specimen exhibits well the well-known valuable properties of the material, requiring 45 foot-pounds to twist it 10 deg., reaching a limit of elasticity at 54 foot-pounds and 13 deg., and having a maximum resisting moment of 59½ foot-pounds. When it finally yields, it does so quite rapidly, breaking off at 145 deg.

Locust, 11, 11, 11, gives an excellent

PLATE I.

Autographic Strain-Diagrams of Woods produced by the Testing Machine of Professor R. H. Thurston.

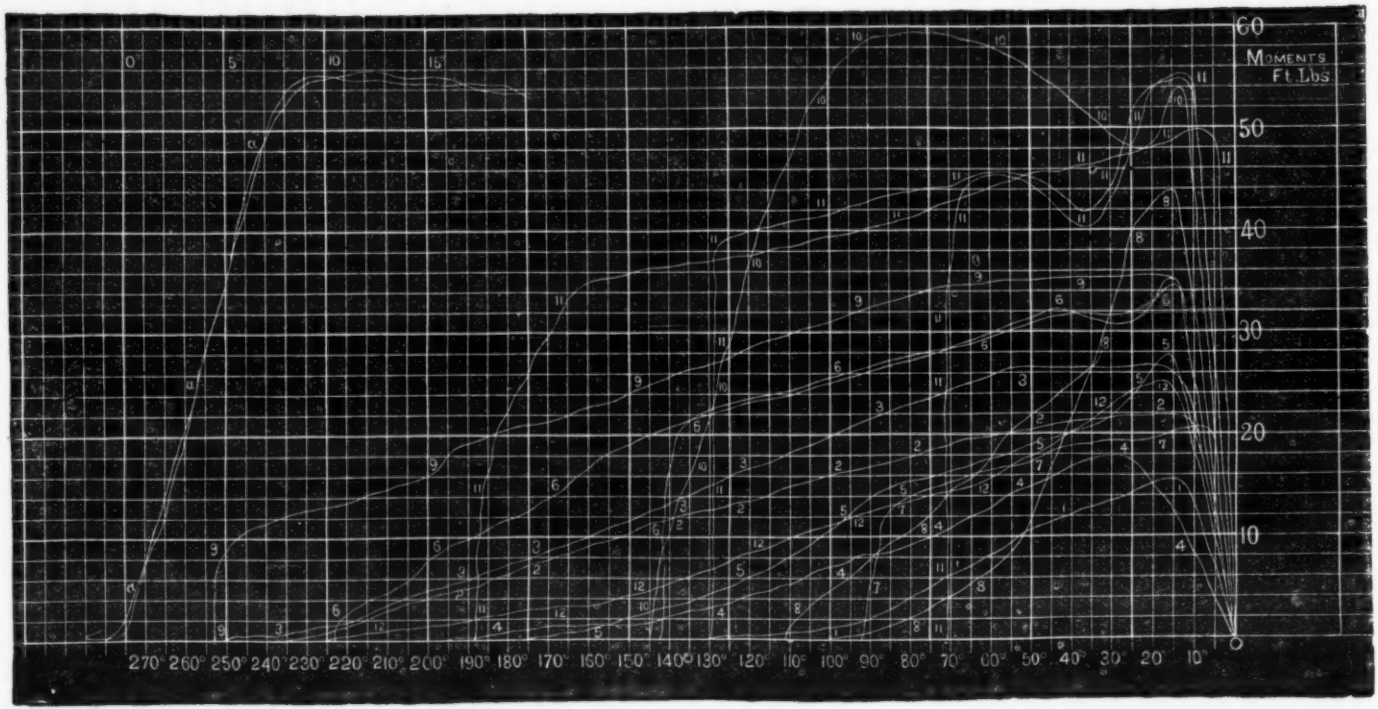


diagram. It is the stiffest of all, yielding but 10 deg. at its maximum of 55 foot-pounds, and one piece, which was unusually hard and compact, requiring 48 foot-pounds to distort it 4 deg., and reaching a maximum angle of torsion of nearly 190 deg.

It was noticed, during this series of experiments, that different specimens of the same species of wood usually exhibited very nearly equal strength and rigidity, and that marked differences were only occasionally noted in elasticity and resilience.

6. *The Metals, and the Curves produced by them.*—Plate II. exhibits a series of curves which illustrate well the general characteristics and the peculiarities of representative specimens of the principal varieties of useful metals. In some cases two specimens have been chosen for illustration, of which one presents the average quality, while the other is the best and most characteristic of its class.

The diagrams obtained by testing metals are quite different in general character from those registered in experiments on the woods, yet there are some points of resemblance which it will be instructive to notice, since these similar characteristics indicate similar properties of the two materials, and a comparison aids greatly in the interpretation of the diagrams. The woods have a structure which differs, in a distinguishing degree, both in the distribution of the substance and in the action of those molecular forces capable of resisting rupture, from that of the metals, the latter being far more homogeneous, in both respects, than the former. Wood consists of an aggregation of strong fibres, lying parallel, or approximately so, and held together often by a comparatively feeble force of lateral cohesion. The latter force being, as often happens, destroyed, the mass becomes a collection of loose threads having the general character of a rope or cord, with slight or no twist. The metals, on the other hand, are naturally homogeneous, both in structure and in the distribution and intensity of the molecular forces. Well-worked and thoroughly annealed cast-steel, as an example, is equally strong in all directions, is perfectly uniform in its structural character, and is almost absolutely homogeneous as to strain. It would be expected, therefore, that the diagrams obtained by breaking such a material would differ from those of the woods, in having a smoother and more regular form, and this is shown to be actually the case by observation of the curves of cast-steel, cast-iron, bronze, and others of the more homogeneous metals and alloys.

Some of the metals, it will be noticed, yield diagrams of less regular form. Wrought-iron, as usually made, has a somewhat fibrous structure, which is produced by particles of cinder, originally left in the mass by the imperfect work of the puddler while forming the ball of sponge in his furnace, and which, not having been removed by the squeezers or by hammering the puddle ball, are, by the subsequent process of rolling, drawn out into long lines of non-cohering matter, and produce an effect upon the mass of metal which makes its behavior, under stress, somewhat similar to that of the stronger and more thready kinds of wood. In the low steels, also, in which, in consequence of the deficiency of manganese accompanying, almost of necessity, their low proportion of carbon, this fibrous structure is produced by cells and "bubble holes" in the ingot, refusing to weld up in working, and drawing out into long microscopic, or less than microscopic, capillary openings.

In consequence of this structure we find, as we should have anticipated, a depression interrupting the regularity of their curves, immediately after passing the limit of elasticity, precisely as the same indication of the lack of homogeneousness of structure was seen in the diagrams produced by locust and hickory.

The presence of internal strain constitutes an essential peculiarity of the metals which distinguishes them from organic materials. The latter are built up by the action of molecular forces, and their particles assume naturally, and probably invariably, positions of equilibrium as to strain. The same is true of naturally formed organic substances. The metals, however, are given form by external and artificially produced forces. Their molecules are compelled to assume certain relative positions, and those positions may be those of equilibrium, or they may be such as to strain the cohesive forces to the very limit of their reach. It even frequently happens, in large masses, that these internal strains actually result in rupture of portions of the material at various points, while in other places the particles are either strongly compressed, or are on the verge of complete separation by tension. This peculiar condition must

evidently be of serious importance, where the metal is brittle, as is illustrated by the behavior of cast-iron, and particularly in ordnance. Even in ductile metals it must evidently produce a reduction in the power of the material to resist external forces. This condition of internal strain may be relieved by annealing hammered and rolled metals, and by cooling castings very slowly, in order that the particles may assume, naturally, positions of equilibrium. In tough and ductile metals, internal strain may be removed by heating to a high temperature and then cooling under the action of a force approximately equal to the elastic resistance of the substance. This process, called "Thermo-tension," was first used by Professor Johnson in the course of his experiments as a member of a Committee of the Franklin Institute, in 1836,* and the effect of this action in apparently strengthening the bars so treated, was stated in the report of the committee. The fact that this effect was very different with different kinds of iron was also noted, but it does not appear that the cause of this, which they term "an anomalous" condition of the metal was discovered by them.

Metals which are very ductile may frequently be relieved of internal strain, also, by simply straining them while cold to the elastic limit, and thus dragging all their particles into extreme positions of tension, from which, when released from strain, they may all spring back into their natural and unstrained positions of equilibrium. This fact, which does not seem to have been previously discovered by investigators of this subject, will be seen to have an important bearing upon the resisting power of materials, and upon the character of all formulas in which it may be attempted to embody accurately the law of resistance of such materials to distorting or breaking strain.

Since straining the piece to the limit of elasticity brings all particles subject to this internal strain into a similar condition, as to strain, with adjacent particles, it is evident that indications of the existence of internal strain, and through such indications a knowledge of the value of the specimen, as affected by this condition, must be sought in the diagram, before the sharp change of direction which usually marks the position of the limit of elasticity is reached. As already seen, the initial portion of the diagram, when the material is free from internal strain, is a straight line up to the limit of elasticity. A careful observation of the tests of materials of various qualities, while under test, has shown that, as would, from considerations to be stated more fully hereafter, in treating of the theory of rupture, be expected, this line, with strained materials, becomes convex towards the base line, and the form of the curve, as will be shown, is parabolic. The initial portion of the diagram, therefore, determines readily whether the material tested has been subjected to internal strain, or whether it is homogeneous as to strain. This is exhibited by the direction of this part of the line as well as by its form. The existence of internal strain causes a loss of stiffness, which is shown by the deviation of this part of the line from the vertical to a degree which becomes observable by comparing its inclination with that of the line of elastic resistance, obtained by relaxing the distorting force—*i. e.*, the difference in inclination of the initial line of the diagram and the lines of elastic resistance, e, e, e, indicates the amount of existing internal strains.

7. *Forged Iron.*—In Plate II. the curves numbered 6, 1, 22 and 100, are the diagrams produced by three characteristic grades of wrought-iron. The first is a quality of English iron, well known in our market as a superior metal. The second is one of the finest known brands of American iron, and the third is also American make, but it does not usually come into the market in competition with well known irons, in consequence of the high price which is consequent upon the necessary employment of an unsual amount of labor, in securing its extraordinarily high character.

No. 6 at first yields rapidly under moderate force, only about 50 foot-pounds of torsional moment being required to twist it 5 deg. It then rapidly becomes more rigid, as the internal strains, so plainly indicated, are lost in this change of form, and at 6 deg. of torsion, the resistance becomes 60 foot-pounds, as measured at a. Here the elastic limit is reached. The next 3 deg. produce no increase of resistance. This fact shows that this iron, which was not homogeneous as to strain, is also not homogeneous in structure. We conclude that it must be badly worked and seamy, and that it may have been rolled

* Journal Franklin Institute, 1836—7.

too cold; the former is the probable reason of its lack of homogeneous structure, the latter gave it its condition of internal strain. After the first 9 deg. of torsion, resistance steadily rises to a maximum, which is reached only when just on the point of rupture, and the piece finally commences breaking at 250 deg., and is entirely broken off at 285 deg. Its maximum elongation, whose value is proportionable to the reduction of section noted with the standard testing machines, is 0.691. The terminal portion of the line, after rupture commences, is not usually accurate as a measure of the relation of the force to the distortion. The increase of resistance between the angle 9 deg. and the angle of rupture is produced by the additional effort in resistance due to the "flow" or drawing out of particles, as already indicated, and the precise effect of which will be noticed at length in a succeeding section relating to the theory of rupture.

Applying the scale for tension, which in the case of these curves was very exactly 24,000 pounds per sq. in. for each inch measured vertically on the diagram, we find that the elastic limit was passed under a stress equivalent to a tension of 19,800 pounds per sq. in., and that the ultimate tenacity was 59,200 pounds per sq in. When nearly at the maximum the specimen was relieved from stress, the pencil descending to the base line, and the elasticity of the piece produced a certain amount of recoil. The angle intercepted between the foot of this nearly vertical line, *c*, and the origin at *o*, measures the set, which is nearly almost entirely permanent. The distance measured from the foot of the perpendicular, let fall upon the axis of abscissas, from the head of this line to the foot of the line *e*, measures the elasticity, and is inversely proportional to the modulus. A comparison of the inclination of the line made by the pencil in reascending, on the renewal of the strain with the initial line of the diagram, gives the indication of the amount of internal strain originally existing in the piece.

It will be noticed that the horizontal movement of the pencil is recommenced at I, under a higher resistance than was recorded before the elastic line was formed. In this case the piece has been left under strain for some time before the stress was relieved, and the peculiarity noted is an example of an increase of resistance under stress,* or more properly of the elevation of the elastic limit, of which more marked examples will be shown subsequently.

The exceptional stiffness and limited elastic range here shown, as compared with the other examples given, is probably a phenomenon accompanying and due to this increase of resistance under stress.

Examining No. 1 in a similar manner, we find that it is far freer from internal strain than No. 6, its initial line being much more nearly straight and rising more rapidly. It is rather less homogeneous in structure, and is forced through an arc of 6 deg., after having passed its elastic limit, before it begins to offer an increasing resistance. It is evidently a better iron, but less well worked, and, as shown by the position of the elastic limit, is somewhat harder and stiffer. No. 1 retains its higher resistance quite up to the point at which No. 6 received its incidental accession of resistance by standing under strain, and the two pieces break at, practically, the same point, No. 1 having slightly the greater ductility. When the "elastic line," *e*, is formed, just before fracture, it is seen that No. 1 has a greater elastic range and a lower modulus than No. 5. It should be observed that the line by which the pencil descends to the base line has usually no value, owing to the fact that no care is generally taken to remove the stress as gradually as it is applied. When such care is taken, the lines are usually coincident, and do not form the loop here seen. It will also be noticed that these lines often cross each other, that on the right being the important line. The elastic line formed by No. 1 at between 40 deg. and 45 deg. of torsion is seen to be very nearly parallel with that obtained near the terminal portion of the diagram, and illustrates the fact here first revealed to the eye, that the elasticity of the specimen remains practically unchanged up to the point of incipient rupture, and this fact corroborates the deductions of Wertheim† and others who came to this conclusion from less satisfactory modes of research. All experiments yet made give a similar result.

No. 22 illustrates the characteristics of a metal which probably represents one of the best qualities of wrought iron made in this or in any other country, and with which

* *Vide* Transactions, Vol. II., page 290.
† *Vide* Annals de Chimie et de Physique.

every precaution has been taken to secure the greatest possible perfection, both in the raw material and in its manufacture. The fact that it finds a market at sixteen cents a pound proves that even such care and expense are well applied. The line of this diagram, starting from *O*, rising with hardly perceptible variation from its general direction, turns, at the elastic limit, *a*, under a moment of about 80 foot-pounds, equivalent to a tension of about 24,000 lbs. per sq. in.; and with between 2 deg. and 3 deg. of torsion only, and thence continues rising in a curve almost as smooth and regular as if it had been constructed by a skilful draughtsman. Reaching a maximum of resistance to torsion of 220 foot-pounds and an equivalent tensile resistance of over 66,000 lbs. per sq. in., at an angle of 345 deg., it retains this high resistance up to the point of rupture some 358 deg. from its starting point. The maximum elongation of its exterior fibres is 1.2, making them at rupture 2.2 times their original length. This would produce a probable breaking section in the common testing machine equal to 0.4545 of the original section.*

From the beginning to the end this specimen exhibits its superiority, in all respects, over the less carefully made irons, Nos. 1 and 6, which, it should be remembered, are themselves deservedly known as good brands. The homogeneousness of No. 22 is almost perfect, both in regard to strain and to structure, the former being indicated by the straightness of the first part of the diagram and its parallelism with the "elastic line," *e*, produced at 217½ deg., and the latter being proven by the beautiful accuracy with which the curve follows the parabolic path indicated by our theory as that which should be produced by a ductile homogeneous material. At similar angles of torsion, No. 22 offers invariably much higher resistance than either Nos. 1 or 6, and this superiority, uniting with its much greater ductility, indicates an immensely greater resilience. It is evident that for many cases, where lightness combined with capacity to carry live loads and to resist heavy shocks are the essential requisites, this iron would be by far preferable, notwithstanding the cost of its manufacture, to any of the cheaper grades. Comparing their elasticities, as shown at 210 deg., 215 deg., it is seen that No. 22 is about equally stiff and elastic with No. 1, while both have a wider elastic range and are less rigid, and hence are softer than No. 6, whose elastic line is seen at 221 deg. All of the characteristics here noted can be accurately gauged by measuring the diagrams, and constants are readily obtained for all formulas, as illustrated in a later section of this paper, in which the construction of formulas and the determination of constants will be made the subject of investigation.

No. 100 is the curve obtained from a piece of Swedish iron, marked [GF]. Its characteristics are so well marked that one familiar with the metal would hardly fail to select this curve from among those of other irons. Its softness and its homogeneous structure are its peculiarities. Its curve, at first, coincides perfectly with that of No. 6. It has, however, slightly less of the condition of internal strain, and a somewhat higher limit of elasticity. The elastic limit is found at 5½ deg. of torsion, and at a stress of 65 foot-pounds of moment, equivalent to 19,500 pounds on the sq. in., in tension. Its increase of resistance, as successive layers are brought to their maximum and begin to flow, is very nearly the same as that of the specimens Nos. 1 and 6, and the line lies between the diagrams given by these irons up to 30 deg., and then falls slightly below the latter. At 220 deg., it attains a maximum resisting power, and here the outer surface begins to rupture, after an ultimate stretch of lines formerly parallel to the axis, amounting to 0.564. Had this elongation taken place in the direction of strain, as in the usual form of testing machine, it would have produced a reduction of section to 0.64, the original area.* At this point the stress in tension equivalent to the 176 foot-pounds of torsional stress, is 52,800 pounds per sq. in. From 250 deg. the loss of resistance takes place rapidly, but the actual breaking off of the specimen did not occur until it had been given a complete revolution. This part of the diagram distinguishes the metal from all others, and shows distinctly the exceptionally tough, ductile, and homogeneous character which gives the Swedish irons their superiority in steel making. No. 22,

* Compare Kirkaldy; Strength of Iron and Steel; pp 111, 115, for reduction in Yorkshire and Swedish bars. The elongation there given has, of course, no value as a measure of ductility.

* Compare Styffe; Strength of Iron and Steel; p. 133, Nos. 26—30.

even, although much more extensible, is harder than No. 100, and yields more suddenly when it finally gives way.

A comparison of the results here recorded with those obtained by Styffe,* will afford a good basis upon which to form an idea of the accuracy as well as the convenience of this method of deriving them. An examination of the broken test piece gives some evidence confirmatory of the record. The exterior surface of the twisted portion has an appearance intermediate between that of No. 1, Fig. 5,† and No. 22, Fig. 7, with an evident tendency to "kink." The surface of fracture is lighter and more lead-like than even No. 22, and its "fibre" is finer and texture more plastic in appearance. It is beautifully uniform in character. On one end of this specimen, where a piece had been nicked and then broken off by a sharp blow, the absence of all fibrous appearance, and the granular texture and magnificently fine, regular grain are very marked, and indicate that the material is entitled to its established position as the purest metal known in the market. The specimens themselves furnish almost as valuable information, after test, as the diagrams contain, and should always be carefully inspected with a view to securing additional or corroborative information. Fig. 5 is a sketch of specimen No. 1, and shows its somewhat granular fracture, and the seamy structure produced by a defective method of working. Fig. 6, from specimen No. 16, more nearly resembles that which gave the diagram marked 6. The metal is seen to be good, tough, and better in quality than No. 1, but it is even more seamy, and even less thoroughly worked, as is evidenced by the cracks extending around the neck, and by the irregularly distributed flaws seen on its end.

FIG. 5.

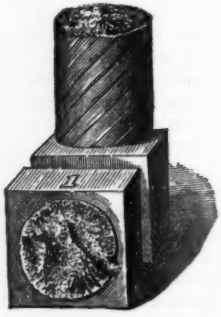
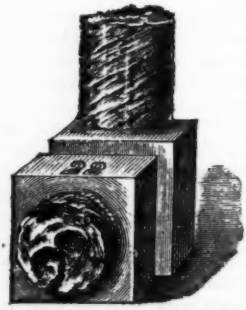


FIG. 6.

Fig. 7 exhibits the appearance of No. 22 after fracture, and shows, even more perfectly than the pencilled record, the splendid character of the material. The surface of the neck was originally smoothly turned and polished, and carefully fitted to gauge. Under test it has become curiously altered, and has assumed a rough, striated appearance, while the helical markings extend completely around it. The end has the peculiar appearance which will be seen to be characteristic of tough and ductile metals, and the uniformly bright appearance of every particle in the fractured section shows how all held together up to the instant of rupture, and that fracture finally took place by true shearing. Rupture by

FIG. 7.



* As on last page.

† From an article in the "Scientific American," of January 17th, 1874, on "Testing the Quality of Iron, Steel and other Metals without Special Apparatus."

torsion thus brings to light every defect and reveals every excellence in the specimen. Rupture by tension rarely reveals more than the mere strength of the material.

8. *Low Steels.*—In Plate II., and above the curves just described, are a set obtained during experiments on "low steels," produced by the Bessemer and Siemens-Martin processes. In general character, the curves are seen to resemble those of the standard irons, as illustrated by Nos. 1 and 6. The irons contain usually barely a trace of carbon. These steels contain from one-half to five-eighths of one per cent. The irons are made by a process which leaves them more or less injured by the presence of impurities, from which the utmost care can seldom free them. The steels are made from metal which has been molten and cast, a process which allows a far more complete separation of slag and oxides. The low steels, however, are liable to an objectionable amount of porosity, due to the liberation of gas while the molten mass is solidifying, whenever the spiegeleisen, employed as a conveyer of carbon, is not very rich in manganese. The results of these differences in constitution and treatment are readily seen by inspecting the curves. They show a stiffness equal to No. 6, and about the same degree of internal strain. They contain a sufficient number of the capillary channels, produced by drawing down the pores while working the ingot into bar, to cause a lack of homogeneousness in structure, very similar to that produced in iron by cinder. They have a much higher elastic limit, and greater strength, and the softer grades have great ductility. In resilience, these softest steels excel all other metals, except the unusual example, No. 22, and are evidently the best materials that are now obtainable for all uses where a tough, strong, ductile metal is needed to sustain safely heavy shocks. A comparison of the diagrams of two competing metals may thus be made to indicate how far a difference in price should act as a bar to the use of the costlier one. For many purposes, a metal having double the resilience of another is worth more than double price. For general purposes, a comparison of the resilience of the metals within the elastic limit is of supreme importance. No. 6 is seen to have more resilience within this limit than No. 1, and the steels far more than either; but No. 1 would take a set of considerable amount far within the true elastic limit, as indicated at *a*. The most valuable measure is obtained by determining the area intercepted between the "elastic line" and the perpendicular let fall from its upper end; this measures the resilience of elastic resistance, which is the really important quality.

No. 98 was cut from the head of an English Bessemer rail made from unmixed Cumberland ores. It contains nearly 0.4 per cent. carbon. It is quite homogeneous, has a limit of elasticity at 88 foot-pounds of torsional, or 26,400 lbs. per sq. in. tensile stress, approaches its maximum of resistance rapidly, and, at 210 deg., the tortional moment becomes 225 foot-pounds, equivalent to 67,500 lbs. per sq. in. tensile stress. It only breaks after a torsion of 283 deg., and with an ultimate elongation of 80 per cent., equivalent to a reduction of cross section to 0.556.

No. 76 is a Siemens-Martin steel made from mixed Lake Superior and Iron Mountain ores, and contained about the same amount of carbon as the preceding. It contains rather more phosphorus, which probably gives it its somewhat greater hardness, its higher limit of elasticity and its somewhat reduced ductility. Its elastic limit is found at 104 foot-pounds of torsion, or 31,200 lbs. tensile resistance, and its ultimate strength is almost precisely that of the preceding specimen. Its elongation is 0.66 maximum. Unless more seriously affected by extreme cold than No. 98, it would be preferred for rails, and, perhaps, for most purposes.

No. 67 is a somewhat "higher" steel, made by the same process. It is less homogeneous than the two just examined, has greater strength and a higher elastic limit, but less ductility. Its resilience is very nearly the same as that of Nos. 98 and 76. The elasticity of all of these steels seems very exactly the same. The ductility of No. 67 is measured by 0.40 elongation. At *d*, is seen another illustration of elevation of the elastic limit. The piece was left twenty-four hours under maximum stress. The torsional force was then removed entirely. On renewing it, as is seen, the resistance of the specimen was found increased in a marked degree.

No. 69 is an American Bessemer steel, containing not far from 0.5 per cent. carbon. The same effect is seen here that was

before noted, an increase of hardness, a higher elastic limit, and greater strength, obtained, however, by some sacrifice of both ductility and resilience. The elastic limit is approached at 130 foot-pounds of torsional moment, or 39,000 lbs. tensile, and the maximum is 280 foot-pounds of moment and 84,000 lbs. tensile resistance at 133 deg. Its maximum angle of torsion is 150 deg., its elongation 0.24.

No. 85 is a singular illustration of the effects of what is probably a peculiar modification of internal strain. It seems to have no characteristics in common with any other metal examined. Its diagram would seem to show a perfect homogeneousness as to strain and a remarkable deficiency of homogeneity in structure. It begins to exhibit the indications of an elastic limit at a, under a torsional moment of 110 foot-pounds, or an apparent tensile stress of 33,000 lbs. per sq. in., and then rises at once by a beautifully regular curve, to very nearly its maximum at 16 deg. and 176 foot pounds. The maximum is finally reached at 130 deg., and thence the line slowly falls until fracture takes place at 195 deg. The maximum resistance seems* to be very exactly 60,000 lbs. to the square inch. Its maximum elongation for exterior fibres is about 0.23. The resilience taken at the elastic limit is far higher than with common iron, and it is seen that this metal, in many respects, may compete with steel. Its elasticity is seen to remain constant wherever taken. This singular specimen was a piece of "cold rolled" iron. It is probably really far from homogeneous as to strain, but its artificially-produced strains are symmetrically distributed about its axis, and being rendered perfectly uniform throughout each of the concentric cylinders into which it may be conceived to be divided, the effect, so far as this test, or so far as its application as shafting, for example, is concerned, is that of perfect homogeneousness. The apparently great deficiency of homogeneousness in structure is readily explained by an examination of the pieces after fracture; they are fibrous and have a grain as thread-like as oak; their condition is precisely what is shown by the diagram, and the metal itself is as anomalous as its curve.

* With an exceptional case, of which this is an example, the scale for tension is incorrect. The tensile strength is probably higher than here given.

8. *Tool Steels.*—The "tool steels" differ chemically from the "low steels" in containing a higher percentage of carbon, and usually in being very nearly, if not absolutely, free from all injurious elements. They are made in crucibles, by melting down the blister steels, which are the crude product of the process of cementation, or sometimes, by melting a charge composed of selected iron, a small proportion of manganese bearing alloy and the proper amount of carbon. Containing a higher proportion of carbon than the preceding class of metals, it is comparatively easy to secure homogeneousness by the introduction of manganese, and by the same means, to eliminate very perfectly the evil effects of any small proportion of sulphur that may be present. Their comparatively large admixture of carbon makes them harder and reduces their ductility, and since the reduction of ductility occurs to a greater degree than the increase of strength, the effect is also to reduce their resilience. The working of these metals is more thorough than is that of the less valuable steels, or of iron. They are cast in comparatively small ingots, and are frequently drawn down under the hammer, instead of in the rolls, and are thus more completely freed from that form of irregularity in structure noticed so invariably in steels otherwise treated The effect of increasing the proportion of carbon, is to confer upon iron the property of hardening, when heated to a high temperature and suddenly cooling, and the invaluable property of "taking a temper," *i. e.*, of assuming, under proper treatment, any desired degree of hardness. The hard steels are, however, comparatively brittle, the hardening being secured at the expense of ductility. The effect produced upon the tenacity of unhardened steel, by increasing proportions of carbon is somewhat variable, since it is influenced greatly by the presence of other elements. For good steels, unhardened, the writer has been accustomed to estimate tenacity by the following formula, which is approximately accurate, and may be often found useful:

$$T = 60{,}000 + 70{,}000\ C.$$

in which T represents the tenacity in pounds per square inch, and C is the percentage of carbon contained in the metal. This subject will be considered at greater length after a series of experiments have been made to obtain more exact determinations.

Referring to Plate II., a set of diagrams will be found, having their origin at 180 deg., which are *fac similes* of those automatically produced during experiments upon various kinds of tool steels.

No. 58 is an English metal, known in the market as "German crucible steel." It is remarkable as having a condition of internal strain which has distorted its diagram to such an extent as to completely hide the usual indication of the elastic limit. A careful inspection shows what may be taken for this point at about 14½ deg. of torsion, when the twisting moment was about 120 foot-pounds, and the tensile resistance 36,000 pounds per sq. in. The metal is homogeneous in structure, has an ultimate resistance of 302 foot-pounds of moment, or 90,600 pounds per sq in. tensile resistance. Its resilience is evidently inferior to that of the softer metals, and also less than the next higher and better grades. This metal contains about 0.60 to 0.65 per cent. carbon. Its elongation amounts to 0.045.

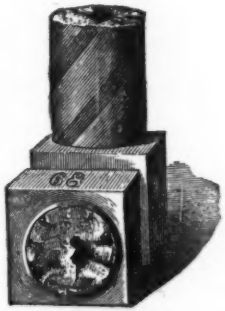
No. 53 is an English "double shear steel," of evidently very excellent structure, but less strong and less resilient than the preceding. Its exterior fibres are drawn out 3 per cent.

Nos. 41 and 61 are two specimens of one of the best English tool steels in our market. The first was tested as cut from the bar, but the second was carefully annealed before the experiment. In this instance, annealing has caused a slight loss of resilience as well as a decided loss of strength. In No. 41, the limit of elasticity can hardly be detected, but seems to be at about the same point as in No. 61, at near 130 foot-pounds moment and 39,000 pounds tension. The ultimate strength is nearly 119,000 pounds per sq. in. The proportion of carbon is very closely 1 per cent. Its section would reduce by tension, 0.05.

No. 70 is an American "spring steel," rather hard, but, as shown by its considerable resilience, of excellent quality, resembling remarkably the tool steel No. 41. It differs from the latter, apparently by its much higher elastic limit. It is possible that this may have been caused by more rapidly cooling after leaving the rolls in which it was last worked. It is evident that, for exact comparison, all specimens should be either equally well annealed or should be tempered in a precisely similar manner, and to the same degree

Nos. 71 and 82 are American tool steels, containing about 1.15 of carbon. The former is notable as having an elastic limit at 69,000 pounds, and a probable deficiency of manganese, producing the usual indication of heterogeneous structure. Both of these steels lack resilience, and are less well adapted for tools like cold chisels, rock drills, and others which are subjected to blows, than for machine tools. They have a maximum elongation, respectively, of but 0.013 and 0.03.

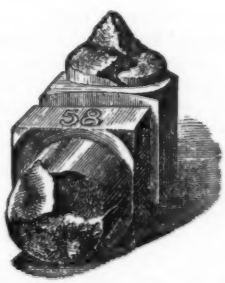
FIG. 8.



Interesting and instructive as the study of these curves may be made, the information obtained from them is supplemented, in a most valuable manner, by that obtained by the inspection of the fractured specimens, upon which the peculiar action of a torsional strain has produced an effect in revealing the structure and quality of the metal that could be obtained in no other way.

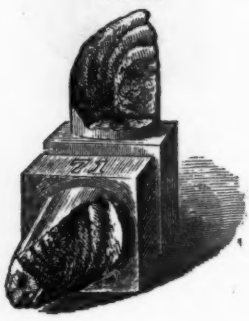
Fig. 8 represents the appearance of No. 68, and Fig. 9 that of No. 58, while the peculiarities of the finest tool steels are seen in No. 71, as shown in Fig. 10. The

FIG. 9.



smooth exterior of No. 68, which is a companion specimen to that giving diagram 69, and its bright and characteristic fracture, resembling that of No. 22 somewhat, together indicate its nature perfectly, the first feature proving its strength and uniformity of structure, and the second showing, even to the inexperienced eye, its toughness. This is a representative specimen of low steels. No. 58 is seen to have retained even more than No. 68, its original smoothly polished surface. Its fracture is less waxy, and much more irregular and sharply angular. The crack running down the side of the neck shows its relationship to the shear steels which much oftener exhibit this effect of strain, in consequence of their lamellar character. No. 58 is evidently intermediate in its character between the soft steels, like No. 68, and the tool steels which are represented by No. 71, Fig. 10. In this test piece, the

FIG. 10.



fracture is ragged and splintery, and the separated surfaces have a beautifully fine even grain, which proves the excellence of the material. The surface which was turned and polished in bringing the metal to size remains as perfect as before the specimen was broken. By an inspection of the broken test pieces in this manner, the grade of the steel, and such properties also as are not revealed by an examination of the diagram of strain, are very exactly ascertained by a novice, and to the practical eye, the slightest possible variations of character are readily distinguishable.

9. *Cast-iron.*—The diagrams of strain having their commencement at 100 deg., have been obtained from cast-iron and from malleableized cast-iron.

Nos. 23 and 24 are those given by a good dark grey foundry iron from Pennsylvania. No. 25 represents the curve of light grey scrap, and No. 30 is from a very fine white Lake Superior charcoal iron. The latter is seen to be exceedingly hard and rigid, the resistance of the piece rising very precisely in proportion to the angle of torsion until it snaps at last under a moment of over 200 foot-pounds, equivalent to a tension of 60,000 lbs. per sq. in., and with a maximum elongation of one-tenth of one per cent. This is a most extraordinary resistance, but it is evident that, notwithstanding its immense strength, this material would be valueless for ordinary purposes in consequence of its excessive brittleness. When the torsional effort had reached about one-half its maximum amount the piece was released. The pencil retreated along a nearly vertical line *e*, which it again traversed as the strain was gradually renewed. Here as in many other cases, where a similar experiment was made, evidence is given of the truth of the statement originally made by Hodgkinson,* that every load produces a set. As will be shown, subsequently, however, it is not true in perfectly homogeneous bodies free from strain, and within their elastic limit. The light grey iron has a limit of elasticity at near one half the maximum reached by the white iron, without any sign of reaching the limit of its elasticity. The grey has more ductility than the white iron, but has only about two-thirds the resilience of the latter. The dark grey irons are evidently better than either of the lighter grades, except in power of carrying an absolutely static load. The actual stretch of the outer surface particles is very nearly the same in all three. They are excellent specimens of their class, and considerably better than ordinary irons.

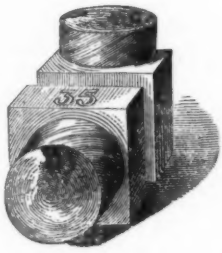
No. 37 is a "malleableized cast-iron," made from the extraordinary metal illustrated in No. 30. The process of malleableizing consists in decarbonization by heating the casting made from good white iron, in contact with iron oxide or other decarbonizing material. Without removing any other constituent than the carbon, it produces a crude steel or an impure wrought-iron. When performed in the usual manner, melting the cast-iron in a cupola in contact with the fuel, and with some flux,

* Reports of British Association; also Civil Engineer and Architect's Journal.

and then carrying the process of malleableizing to the usual extent, a metal is obtained such as is illustrated by the diagram marked 37. It retains the strength of the cast-iron, and acquires some ductility.

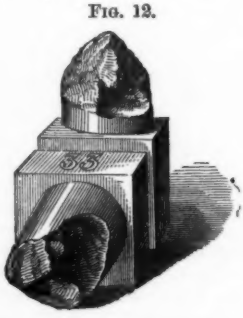
No. 30 yielded 7 deg. before fracture, while No. 37, vastly more ductile and resilient, only broke after a torsion of 39 deg., and a maximum elongation of 2 per cent. Taking the precaution to melt the iron in an "air furnace"—a form of "reverberatory"—and conducting the process of malleableizing more carefully, a still more valuable material was obtained.

FIG. 11.



No. 35 represents this iron. Its resemblance to wrought-iron, both in appearance of fracture and in its strength and ductility, are greatly increased. It has a high limit of elasticity—over 20,000 lbs. per sq. in.—and such ductility that it only breaks after a torsion of nearly 168 deg., and an elongation of "fibre" of 0.35. It is not very

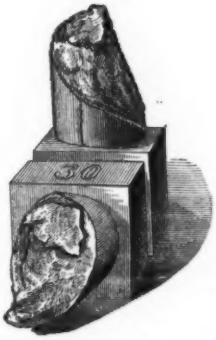
FIG. 12.



homogeneous, but it is as strong, and almost as tough as a good wrought-iron. This material has especial value for many purposes, because of the facility with which awkwardly shaped pieces can be made of it. In many cases, it will prove as good as wrought-iron and far cheaper.

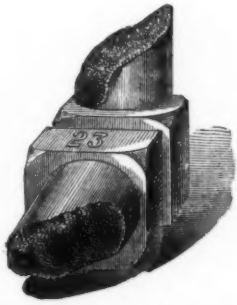
Fig. 11 shows the appearance of this last specimen. Its resemblance to wrought iron is very noticeable. The lines running like the thread of a screw around the exterior of the neck, and the smooth even fracture in a plane precisely perpendicular to the axis, are the instructive features. Fig. 12, representing No. 33, is a specimen similar in character to No. 37. The comparative lack of ductility, its less regular structure, and its less perfect transformation are perfectly exhibited. Fig. 13 is an excellent cut of

FIG. 13.



the white iron as cast and without malleableizing. Its surface where fractured, has the general appearance of broken tool steel. The color and texture of the metal are distinctive, however. It has none of the "steely grain." Fig. 14 represents the

FIG. 14.



dark grey iron. Its color, its granular structure and coarse grain are markedly characteristic, and no one can fail to per-

ceive, in the specimen, the generel character which is exactly given by the autographic diagrams of the testing machine.

10. *Other Metals.*—The diagrams numbered 87, 88 and 89, are those of copper, tin and zinc. These specimens are all of cast metal, carefully selected under the direction of the writer and moulded and cast at the Stevens Institute of Technology. They exhibit neatly the wonderful superiority which the various kinds of iron and steel possess over the other useful metals. These metals all take a set under very small strains, pass their limits of elasticity at some indeterminable, but evidently low point, and possess very slight tenacity.

Zinc, No. 89, by the regularity of its curve shows a very uniform structure. It increases very gradually in resistance to torsion, until it reaches the angle 50 deg., at which point it has a moment of torsional resistance of 36 foot-pounds, and a maximum tenacity of about 10,800 lbs. per sq. in. It loses its power of resistance, after rupture commences, as regularly, but not as slowly, as it acquired it, and rupture becomes complete at 63 deg. Its resistance is exceedingly small, and it is evidently unfit to bear either static or dynamic force. Its stretching power has a maximum of 0.04.

Tin, No. 88, is equally remarkable for its exceedingly feeble resistance and its great ductility. The specimen was excellent, both in quality of metal and in closeness of structure, as was indicated by the clearness of the "tin cry" heard while undergoing the test, and by the fine, smooth, clean fracture. The character of the curve is similar to that of zinc, but has far greater extent. Its elastic limit is quite indeterminable. The outline of the diagram indicates very perfect homogeneousness. The maximum resistance to torsion is found at 240 deg., and under a stress of 19 foot-pounds. Its tenacity deduced from the diagram is, at most, but 5.700 lbs. per sq. in. Rupture occurs very gradually, and the piece separated entirely at 355 deg. Notwithstanding its great ductility, its low tenacity produces a low resilience, although in this quality it excels zinc, which latter metal had nearly double its strength. Its elongation by tension would have reduced its section to 0.6 of the original cross area, if that reduction were proportional to the ductility shown by the diagram.

Copper, No. 87, cast in green sand, like the zinc and tin just described, was found, on examination of the fracture, to differ from them in being exceedingly porous. The effect of this fault has been to weaken it seriously. Its curve closely resembles that of zinc, but is abruptly terminated by the piece suddenly breaking off at 46 deg. It reaches a maximum sooner than zinc, at 29 deg., and its greatest resistance to torsion is 36 foot-pounds, or to tension 10,800 lbs. per sq. in., precisely the same as zinc. Its ductility has a value of one and a half per cent. Its resilience is somewhat less than that of zinc. Its limit of elasticity is difficult to determine, but has been taken at $1\frac{1}{2}$ deg. where the moment of resistance is 13 foot-pounds, equivalent very nearly to 3,900 lbs. tenacity per sq. in.

No. 134 is the curve of cast copper, precisely similar to No. 87, but cast in a dry sand mould. The marked difference between these specimens is probably due, not only to the difference in degree of porosity which arises from the presence of vapor, which permeates the casting in one case, filling it with bubble holes, and which is almost unobservable in the last, but the slower cooling of the dry sand casting also probably produces its effect in strengthening the metal. This last specimen has a limit of elasticity at not far from $13\frac{3}{4}$ deg., and under a torsional stress equivalent to a tension of 5,400 lbs. per sq. in. The maximum values of these quantities are found at 21 deg., and are 42 foot-pounds, and 12,600 lbs. per sq. in. respectively. The resilience of the specimen is much greater than that of the preceding, and its maximum elongation is .026. Altogether, this is far better than the preceding, and it would seem that copper, and probably all its alloys, should, when possible, be cast in dry sand, to secure density and strength.

No. 141 is a piece of forged copper, hammered into a one-inch square bar, from a piece originally $3\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. thick. The most striking property noticed is its immense ductility, far exceeding that of any other piece of metal yet tested, and, in amount, many times as great as the cast metal. Its limit of elasticity is reached very quickly, although it is impossible to say precisely where it occurs. Comparing its "elastic line" with the initial portion of the curve, it is seen that the slightest force produces a set which is proportionally large as compared with the sets of other metals.

The curve rises very regularly and gradually to a maximum, which is only attained, however, after a total angle of tension of 450 deg., and which measures 96 foot-pounds moment, or 28,800 lbs. per sq. in. Rupture is finally obtained after a torsion of 543 deg. The maximum elongation is 210 per cent., the most elongated lines of particles being finally left of 3.100 times their original length. Had this change of form occurred by reduction of section, the fractured area would have been but .323 the area of original section. The resilience of this piece of metal is evidently insignificant within the limit of which it would be seriously distorted by a blow, but is quite large in amount where resistance extends to the point of rupture. This is perfectly consonant with that knowledge of the material which every mechanic derives from experience with it. Here, however, we have a complete account of its properties, written out by the material itself with definite and accurate measures.

11. *General Conclusions.*—These plates, exhibiting the diagrams, which are the autographs of all the useful metals, illustrate sufficiently well the remarkable fulness and accuracy with which their properties may be graphically represented, and the convenience with which they may be studied, with the aid of so simple a recording machine. A comparison of results deduced as shown, with those obtained, so far as they can be obtained at all, the usual method of simply pulling the specimens asunder, and trusting to, sometimes, unskilful hands and an untrained observer, for the adjustment of weights and the registry of results, will indicate the close approximation of this method in even ascertaining the behavior of the metal in tension. On examining the beautifully-plotted curves given by Knut Styffe, as representing the results of the experiments made by him and by his colleagues, with a tensile machine, no one can fail to be struck with the similarity of those diagrams to the curves here produced automatically, and it will be readily believed that not only must there be very perfect correspondence of results where the two methods are carefully compared, but, also, that any theory of rupture must be defective which does not apply to both cases. The equations of the curves here given and those of the curves obtained by Styffe must have forms as similar as the curves themselves.

The constant ratio here assumed between the torsional resistance and the tensile strength of the metals, and of homogeneous materials generally, is based upon a comparison of the results here given with those obtained from the irons by tensile test, by the writer, and is confirmed by a compilation of results given by other experiments on the same brands.

12. *Testing within the Limit of Elasticity.*—In determining the value of materials of construction, it is usually more necessary to determine the position of the limit of elasticity and the behavior of the metal within that limit, than to ascertain ultimate strength or, except perhaps for machinery, even the resilience. It is becoming well recognized by engineers who are known to stand highest in the profession, that it should be possible to test every piece of material which goes into an important structure and to then use it with confidence that it has been absolutely proven to be capable of carrying its load with a sufficient and known margin of safety. It has quite recently become a common practice to test rods to a limit of strain determined by specification, and to compel their rejection when found to take a considerable permanent set under that strain. The method here described allows of this practice with perfect safety. The limit of elasticity occurs within the first two or three degrees, and, as seen, the specimen may be twisted a hundred, or even sometimes two hundred times as far without even reaching its maximum of resistance, and often far more than this before actual fracture commences. It is perfectly safe, therefore, to test, for example, a bridge rod up to the elastic limit, and then to place the rod in the structure, with a certainty that its capacity for bearing strain without injury has been determined, and that formerly existing internal strain has been relieved. The autographic record of the test would be filed away, and could, at any time, be produced in court and submitted as evidence—like the "indicator card" of a steam engine—should any question arise as to the liability of the builder for any subsequent accident, or as to the good faith displayed in fulfilling the terms of his contract. A special machine has been designed for this case.

13. The above will be sufficient to show the use and the value of this method. In the course of experiment upon a large number of specimens of all kinds of useful

metals and of alloys, a number of interesting and instructive researches have been pursued, and some unexpected discoveries have been made. Before taking up the theory of rupture, the construction of equations, and the determination of their constants, a section will be devoted to an account of these investigations.

ROAD CONSTRUCTION IN THE HIMALAYAS.*

By Maj. JAMES BROWN.

From "Engineering."

The object of this paper was to put on record precautions found necessary whilst making roads among the Himalayas, at elevations reaching up to 24,000 ft.; where the annual rainfall in some districts amounted to 220 in., of which 170 in. fell in the two and a half months of the rainy season, and 5½ in. in one hour. Mountain roads could be divided into two classes: those which crossed the main or higher ranges, and those which crossed the lower or subsidiary ranges. The latter class generally presented the most serious engineering difficulties, owing to the greater quantity of water to be encountered. In the higher ranges, the soil, being mainly composed of hard rock, did not allow every little streamlet to cut for itself a deep and ever-increasing chasm, as in the comparatively soft soil of the lower ranges, and this circumstance rendered the bridging an easier matter. At elevations exceeding 8,000 ft. attention must be paid to the action of the snow in winter. The best approach, in an engineering point of view, to the station of Dalhousie was through a ravine, so sheltered from the sun that the snowdrifts remained unmelted for weeks, and barred the way; and it had been found necessary, in consequence, to take the new cart-road through otherwise very unfavorable ground. At Roksur, in Lahoul, a road well traced, but laid out in the height of summer, was impassable for the three spring months from incessant avalanches; one of which, half a mile in length and exceeding 100 ft. thick, carried off a stone bridge of 40 ft. span, and remained unmelted for more than six months.

In marking out the formation level, cuttings exceeding 10 ft. or 15 ft. in depth should, as much as possible, be avoided. In the stony soil of a hilly country no reliable information was to be got by boring, and rock of the toughest and hardest description sometimes cropped up where least expected. In the Himalayas, the northern slopes were thickly wooded, where the southern slopes were often quite bare. The former should be selected, notwithstanding the increased labor of tracing through the brushwood, as the road would be more durable. The trees broke the force of the rain, and the mould beneath passed it off gently over the road, which, on the bare hillside, would be cut away by the unchecked rush of water.

The general adoption of zig-zags was not to be recommended; but much had been said against them which was open to modification. They entailed incessant repairs, if used in a wrong place—where the side-slope was steep, the soil rotten, and the drainage such as to cross the road several times. But where these conditions did not prevail, the repairs were little, if at all, greater than in the same length of straight tracing. Again, where the reaches were short, and the turning-places cramped, zig-zags should not be tolerated; but where each reach was not less than 600 or 700 yards in length, and where a semicircular turn of not less than 50 ft. radius could be obtained, the inconvenience was small and the danger a minimum. Generally 5.55 in 100 was the steepest admissible gradient for an unmetalled mountain cart-road in India. No earthwork became permanent under two rainy seasons. Landslips occurred with every shower and every hard frost. On the Dalhousie cart-road, the mere cutting out of the hillside to 14 ft. in width determined a landslip upwards of 800 ft. back from the edge of the road, and parallel to it for about 700 ft.

There were three different methods of making a road along the face of vertical cliffs. The most expeditious was to form a gallery, carrying the road on cantilevers of iron or timber. This plan, however, was only suited for mule or bullock roads, and was inapplicable for cart roads. It had

* Read before the Institution of Civil Engineers.

therefore been replaced by half tunnels blasted out of the rock. From the nearest possible standing point a gangway of lashed scaffolding poles was run out horizontally along the face of the cliff, the near end being held down by two leaded jumpers, or by lewises let into the rock. A workman from the further end of the scaffold, drove into the rock a jumper hole, slanting about 45 deg., which, when sufficiently deep, received an iron bar run with lead. To this support scaffolding was lashed, to act as a new starting point from which to advance another step. When the scaffolding so supported had extended along the whole length of the cliff, arrangements could be made for fixing the permanent cradles and cross beams to carry the gallery. On the Hindustan and Thibet road the galleries were 7½ ft. wide, the supporting cradles being from 12 ft. to 15 ft. apart. The other modes of forming a road along the cliffs were either by blasting in the usual manner, or by the use of mining galleries and heavy charges of powder. Where kunkur rock was met with, special cartridges were employed for blasting. This substance resembled petrified sponge, which, whilst allowing the powder to blow out through its pores, was so hard and tough as to defy the best steeled picks and jumpers.

On one section of the Hindustan and Thibet road, adjoining the glaciers, and where wood was abundant, blasting was abandoned for more than a year in favor of wood furnaces, while the fuel lasted. The rock, when intensely heated, and then quickly deluged with snow water, cracked and broke up, at a great saving of time and labor.

The ordinary daily task of native quarrymen in boring was about 60 in. in sandstone or conglomerate, 45 in. in limestone, and from 30 in. to 32 in. in granite. In attacking a cliff with large mines, a line of scaffolding was first erected along the face, and tunnels were driven into the rock, chambers being formed at the ends of return galleries to the right and left. The charges were placed at a horizontal distance from the cliff face of 2 ft. more than the proposed width of the road, and generally blew out the rock on both sides to a distance equal to the line of least resistance. The galleries, which were 3 ft. high by 2 ft. 6 in. wide, could, in conglomerate, be driven at an average rate of 1 in. an hour, and at a cost of about 2s. per lineal foot. The rate of progress was three times and five times less in limestone or granite than in sandstone rock or conglomerate, which rendered mining a tedious operation. The galleries for the most part were chiselled with cold steel and not blasted. The most effectual mode of tamping mines in impracticable localities was by sandbags of date or palm-tree matting, containing about ½ cubic ft. of damp clay. With these and a few half-bags and quarter-bags, the tamping was built up by native masons like an ordinary wall. Cushions of sand greatly increased the effect of the explosion. This systematic method of tamping could be done at the rate of 12 lineal ft. an hour, or three times the rate of tamping with earth, in the usual manner.

Dry masonry retaining walls were largely employed on most Himalayan roads, many of them being of great dimensions and of some constructive difficulty. Sandstone, notwithstanding its clean splitting and good bedding, was by no means so suitable a material for retaining walls as granite or limestone boulders, being liable to disintegrate under tropical rains in damp situations, as in foundations below the level of the ground. Retaining walls of what seemed most compact sandstone had suddenly collapsed, the underground courses having dissolved into sand. Where expensive masonry in mortar was used, great economy resulted from the best possible shape and dimensions being given to retaining walls; but where cheap dry masonry was employed, earth should never be used for the backing, but the space should be filled with boulders or stone chips.

The mere excavation of a wide road along a hillside at once altered the whole system of natural drainage. It was useless to commence any drainage works until the annual rains had marked out the line of discharge across the great catchwater formed by the road. On some parts of the Lahore and Peshawur road the main drains were 25 ft. wide by 5 ft. deep. On the Kangra road they averaged 10 ft. wide by 3 ft. deep. The smallest secondary drains should be 2 ft. by 1 ft. 3 in.; no cross drain, if provided with a movable slab top, being less than 2 ft. by 2½ ft., or, if permanently covered in, less than 2 ft. 3 in. by 2 ft. 9 in. To insure proper scouring, and an easy change of direction for the water, the cross drains had a slope of 1 in 12, and were built at an angle of 135 deg. with the side drain, their

ends being properly secured by boulder pitching. The main drainage was carried across the road through culverts, but more especially through large outlets in dry masonry retaining walls, covered in by stone slabs of from 2½ ft. to 3 ft. span. For larger spans, up to 10 ft., and where slate was procurable, dry rubble arches were built of picked stones neatly radiated and wedged up. Where building stone was scarce, concrete arches on dry masonry abutments were largely employed, the whole mass forming a monolith, rammed up in 4 in. horizontal layers. The Durroon Bridge, on the Kangra road, was 48 ft. span in the clear by 20 ft. wide. The arch was entirely composed of rammed mortar, consisting of one part of boulder lime, one part of pounded brick, and one part of sand, no broken stone whatever being used.

The shape generally given to the metalled road surface on a mountain side was a slope of 1 in 18 from the outside to the inside. It had been objected to this slope that it converted the road into a drain, which was cut away and became impassable in heavy down-pours; and on some of the Madras hill roads the slope was from the inside to the outside. Both systems had their respective advantages; but, on the whole, the inside slope was preferable when the cross drains were sufficiently large and numerous, and the side drains rocky or properly protected by boulder paving. The usual practice was to adopt the outside slope until the drains were built and the side slopes had taken their bearings, when, as a permanent arrangement, the road was finished and metalled with an inside slope. The metalling consisted of a 9 in. layer of broken granite, kunkur rock, or coarse slate shingle, and did not materially differ from an ordinary macadamized surface. The usual width of a mountain cart road varied from 18 ft. in open ground to 12 ft. along cliffs, or in difficult places; the maximum gradients varying 1 in 18 to 1 in 25.

THE ADMIRALTY EXPERIMENTS ON SCREW PROPULSION.

From "The Engineer."

At the Norwich meeting of the British Association in 1868, the attention of the Association was drawn to the deficiency of existing knowledge on the stability, propulsion, and sea-going qualities of ships, and to the need of further experiments as a basis for the extension of theoretical investigation. A committee was appointed for the purpose of reporting on the state of knowledge on these subjects, and it was ultimately resolved by the committee that the Admiralty should be asked to carry out experiments with full-sized vessels upon some suitable water. Mr. Froude, F. R. S., who was a member of the committee, was, however, of opinion that the experiments should—at all events, at first—be carried out with models constructed on some substantial or rational scale. He contended that unless the reliability of small-scale experiments were emphatically disproved, it would be useless to spend vast sums of money upon full-sized trials, which, after all, might be misdirected, unless the ground were thoroughly cleared beforehand by an exhaustive investigation on a small scale. The final result of the application to the Admiralty was that the proposals of the committee for the full-size experiments could not be assented to, but that certain experiments with models, to be conducted by Mr. Froude, would be sanctioned, and the results of these experiments when complete would be communicated to the British Association, the Institution of Naval Architects, and other professional bodies.

We reprint, on another page, an interesting paper, descriptive of an extremely ingenious method of preparing models of ships to be used for such experimental purposes. This paper, which was read at the recent Cornwall meeting of the Institution of Mechanical Engineers by Mr. Froude, gives very full particulars of one part of that gentleman's procedure in conducting these experiments; and in order to give our readers some idea of their nature, of the truly scientific manner—the thoroughness, we may say—in which they are carried out, we add some further information of a general character which can be relied on as substantially correct.

When the design of any model which is to form part of the series under trial has been decided on, the first stage in the proceeding is to prepare in hard paraffine a

sufficiently large model, which shall have, with the most perfect accuracy attainable, the contemplated lines. The models used are from 9 ft. to 16 ft. in length, displacing on an average probably 600 lbs. each. When the design of a model has been decided on, a rough casting of it is made in the paraffine, and its successive water lines are accurately cut by automatic apparatus, which copies on an enlarged scale those of the design; the copying arrangement being such that the ratio of enlargement in each of the three dimensions is independent of the others, so that several successive models of the one and the same fundamental character, yet differently proportioned in length, breadth, and depth, may be produced from the same design.

This is effected by help of set of templates of adjustable curvature, consisting each of a flexible steel ribbon, set off as a curve from a straight edge by adjustable push-and-pull rods which serve as ordinates. The set when duly combined is in effect a small scale skeleton original of the intended model. The templates and the mode of arranging them are fully described in the paper we reprint. It will be seen that they may either be set to a design already decided on, or employed in completing the design. Each of these templates representing one of the water lines is in turn employed in the shaping machine, and serves as a guide to the cutters as the paraffine casting is caused to travel between them; consequently for each template a corresponding line is cut on each side of the paraffine mass, the rough uncut pieces between the lines being subsequently removed by hand in the manner fully described in the paper. When completed, the model hull is placed in the tank, which is nearly 280 ft. long, by between 30 ft. and 40 ft. wide, and 10 ft. deep, and under cover, so as to be completely removed from atmospheric influences. A light railway is suspended from the framing of the roof, traversing the entire length of the tank at about 20 in. above the normal water level, there being a clear space between the rails, the gauge of which is preserved independently of sleepers. A stoutly framed carriage suspended from two pairs of wheels runs on the railway, and is moved by an endless wire rope, coiled in a spiral groove on an accurately turned barrel, which is driven by a small engine having a heavy fly-wheel and a chronometric governor of very exact action, and of such arrangement that any required steady speed between 100 ft. and 1000 ft. per minute can be assigned by it to the carriage.

This carriage supports the dynamometric towing apparatus to which, after having been loaded to the calculated displacement, the model hull is attached. The method of attachment at both stem and stern is such that while the model is perfectly free to move in any direction in a fore-and-aft vertical plane, no lateral deviation whatever is possible. This removes one difficulty which would otherwise exist, for it has been found that whenever it is attempted to tow a model by a single attachment, it invariably disposes itself at an angle to the line of force, even when the point of attachment travels rigidly in a straight line. The extensions of the dynamometer spring, which constitute a measure of the model's resistance, are brought to an enlarged scale by a lengthened index arm, and are self-recorded by a pen which traces a line on a sheet of paper carried by a cylinder put in rotation by a band from a pulley on the hinder axle of the carriage. Thus the circumferential travel of the paper represents on a small scale the forward motion of the truck. A second pen, actuated by a clock, marks given intervals of time on the paper, so that the marked paper supplies information as to the resistance experienced at each point in the run, and also as to the speed at which each portion of the run was performed. Moreover, as the lines of floatation of the model at rest and in motion are different, the vertical elevation or depression at the stem or stern are also recorded by separate pens. And lastly, a careful observation of the configuration of the waves caused by the models in passing is taken by an assistant who stands in a kind of immersed box or well, so that his eye is but little above the level of the water, the sides of model being graduated so as to facilitate the observation.

The series of results obtained at various speeds with each model is graphically represented on a sheet of paper, and constitutes what is termed the "diagram" for that model, containing:—

(1) The "curve of resistance," a figure in which the base line gives the speeds; the ordinates, the corresponding resistances.

(2) A pair of curves shows the alteration

in level of the head and stern at the various speeds.

(3) Carefully drawn representations of the wave profiles.

So much for the experiments with the ship; the behavior of the screw is recorded by other apparatus. For this purpose also a travelling carriage is employed, running on the same rails, but with some interval between it and the former. This carriage is connected with the towing carriage by means of a rigid coupling bar, and consequently the two travel at precisely the same speed. The screw is fitted on the end of a horizontal bar or shaft immersed below the carriage, the end of which projects far enough forward to carry the screw—if required—in its natural position under the model's stern, yet quite independently of the model; or, by varying the length of the coupling bar, at any given distance astern of that position. The screw receives its rotation by a belt from an axle of the truck, and can be "speeded" at pleasure. The carriage of the shaft bearings is a rocking frame, delicately hung, so as to possess an equilibrated parallel motion in a fore-and-aft plane; and the "thrust" of the screw, which forms a forward drag on the frame, is dynamometrically self-recorded; so also is the driving force of the band which gives motion to the screw shaft, as well as the "count" of the screw's revolutions.

By experiment, such a speed is assigned to the screw that its thrust equals the model's actual resistance.

The object of this part of the apparatus is to determine the virtual increase of resistance which is occasioned by the rotation of the screw close to the "run" of model or ship, which diminishes very sensibly the pressure of the water there, and thus in effect very sensibly augments the resistance. The augmentation may amount to 30, 40, or even 50 per cent., according to the fulness of the run and the closeness of the screw to it. The curves of resistance often present curious and rather abrupt variations in the law of resistance in terms of speed, depending apparently on the modifications of the wave configurations which change of speed induces, and which vary characteristically for each individual model.

The circumstance which — according to the views which Mr. Froude has propounded—gives value to experiments with a model, as rendering them capable of true interpretation in relation to the ship it represents, is that the wave configurations will be similar for the model and for the ship whenever their relative speeds are as the square roots of their respective dimensions, or, as Mr. Froude expresses it, are "corresponding speeds;" and that in virtue of this condition it follows that at the "corresponding speeds" the resistances will be as the cubes of the respective dimensions.

This law would have been true on the crude hypothesis which was formerly held, that the resistance of a given form at various speeds was as the square of its speed, and that, comparing small and large similar forms, their resistances were as their respective midship sections. But though, in consequence of the energy expended in the formation of waves, the resistance grows—as has long been known—abnormally as compared with the square of the speed, yet, from the circumstance that the waves generated by similar forms are similar at corresponding speeds, Mr. Froude has shown that the law he proposes holds good under that limitation of speeds.

THE MODERN EUROPEAN STYLE.

By JOHN P. SEDDON.

From "The Architect."

Having taken an early part in the discussion upon a modern European style, I have watched with interest the recent communications to this Journal on the subject. There seems as little unanimity of opinion in them as there is in professional practice of the day, but one and all unite in condemning or damning with faint praise the character of the buildings of the day, upon which pretensions or hopes of an existing or future modern European style are based.

They have but one characteristic, viz., impurity. Let us drop for the nonce all questions of rival styles. There are no such things. Architecture, while a living art, was a sequence, a chain, the separate

links of which we may group as styles for our own convenience to assist memory. First, we see in the remote ages, in the far East, a luxuriance of ill-regulated ornamentation and ponderous unscientific construction, aiming at producing imposing effect by the coarsest and least economical means—size and elaboration. Egypt, Assyria, and Persia thus wrought stupendous works, which formed the quarry for the later architecture of the civilized world. The Greeks founded the art of architecture out of their elements, and in their Doric temple created the Classic order, *par excellence*, for works of imposing dignity. But even this was on a moderate scale as compared with what should be the modulus for terrestrial work—the height of a man. The less logical but more graceful Ionic, and the pretty Corinthian, in their hands, were for lighter and smaller and more decorative works.

Perfect for what it was intended for, but radically external architecture, created for display not use, to be looked at and not dwelt in, Greek architecture is a dead art —like the Classic language—to be studied as models of good proportion, harmony, and the like principles.

The Romans built well and grandly, and foreshadowed in their construction all the "true principles" which formed the characteristics of Mediæval architecture. The Greek had been only trabeate architecture. The Romans built round arches, barrel and groined vaults, but did not see the drift of what they were doing, not being artists. They got the subdued and corrupted Greeks to case their constructions with orders, piled one on the top of another, and destroyed all the consistency of Classic architecture.

Mediæval architecture was but the common-sense use of the same materials, modified to meet new wants. It was but the same art, only no longer used, as by the Greeks, wholly for external show, nor as by the Romans as a mask. It grew naturally out of the plan of the buildings and their interior structure; it was the logical outcome of the round arch, grafted upon the trabeate system, which the Romans had failed to achieve; but the necessities of vaulting compelled the use of the pointed arch, and the Gothic was the necessary result of that more scientific invention.

This is the history of living architecture. Why then are we, who are the heirs of all ages, to go back to an early phase of this sequence? Why should we voluntarily abandon any invention science has given us?

I might have gone on to show how trabeate architecture was the child of the South, where light was not needed and snow is not known; and that the Northern development of Gothic was framed to admit light, and shunt off snow and rain. But what is this but to say that the art of architecture, when living, met every requirement of time and climate? I may ask, however, why we should deliberately go back to any phase of the sequence which was specially suited for other circumstances than our own?

If we have to contrast the two great divisions of the history of architecture—Classic and Mediæval—the essential difference is, not that the one is trabeate only and the other arcuate also, but that the one is what Mr. Henry Conybeare calls *exothenic*, that is, built from without, and the other *esothenic*, that is, built from within; but Greek architecture is true, and the Roman is false *exothenic*.

Now when the career of living architecture was over, and copyism took its place, men reverted to this system of designing the outside first, and unfortunately also to the making this outside architecture a sham.

Architecture became *architecturesque*, that is, it looked like architecture, but was not. It became pinafore architecture, of which there are no styles, but fashions only. True architecture struggled long with it, elsewhere than in Italy, and the Tudor, Elizabethan, Jacobæan, and Queen Anne styles had successively less and less of the true, and more and more of the false. As Professor Kerr described the last-named fashion, it was "the picturesque art of a most unpicturesque time." But whence came the picturesqueness—its one claim to our regard, save delicacy in detail, for which the Classic revival may be credited? Whether is preferable, the general design or its detail? Inigo Jones and Sir Christopher Wren removed the last remnants of the true architecture, and introduced that of the mask—the architecture of dressings. What would the Banqueting Hall at Whitehall, by the former, be without its dressings? what St. Paul's Cathedral without its mask—the whole upper order which hides the roof?

Granted their proportions are good, that is in the former case those of the dressings, for the building is but a square box without them. But we want the buildings before proportions, we want convenience before regularity.

The discussion now seems to be wholly as to the art of architecture on the supposition of the possibility of its severance from the construction. Let the art take care of itself, as it will do in the hands of an artist.

Several of the disputants are unnecessarily complimentary to each other. Courtesy is well, but it should not blunt the edge of weapons in war. I said I agreed with Mr. White, but I could not have understood him. He seems to talk of Gothic as obsolete, and fancies we are coming to Neo-Greek. What, give up the arch and go back to the trabeate! We should then be on a backward track, which, if our dress is to be assimilated, would lead us to the fig leaf.

What we want to return to is pure common-sense architecture. Never mind its name—architecture that first makes a good plan and sound construction, and which abhors a mask that puts no feature not necessary, but makes those beautiful that are necessary. Can this be done with revived Italian? I should rejoice to be shown an example, and then might adopt the style at once. But Italian architecture, without its dressings and reduced to common-sense, what is it? As Mr. Street says, it is just the one step further from Queen Anne to Harley Street. Take Sir G. G. Scott's Foreign Office; architecturesque considerations have made him try to make a five-storeyed building look like a three-storeyed one, and so the lighting of the interior has been sacrificed. Italian regularity of the outside has made a hash of the requisite irregularities within.

Last week I went over a new Italian public structure with centre and wings, imposing enough outside, but I was told over-windowed for its purpose, but that the elevation required. I asked if the apartments were calculated for their use, and was told, not at all; but then that was necessary to make the wings agree. This may be architecturesque, but it is not architectural.

Professor Kerr thinks that we are coming to something suitable to this age, and Mr. Roger Smith anticipates that regularity is what the age is aiming at. How we are to come out of the slough of architectural impurity we are in with clean hands, I cannot see; there is not a feature of Classic architecture not daily murdered before our eyes by those who pretend to reverence it. If there be anything in the proportions of the orders, how can buildings which violate every one of them advance their interests? Regularity is certainly in vogue with the vulgar and with speculating builders; and the rows of terrace-houses of the latter are models of symmetry. The real fact is, this love of regularity is but another form of the canker which destroyed Classic architecture—the attention to the exterior before that of the interior. Let regularity come if it list, as the Gothic architects allowed it, while they refused to be its slaves. Witness the Town Halls in Belgium.

Architecture does not consist in details, so let styles which are known mainly by them be set aside. Let us return to the best phase of past art looked at as a whole, the most comprehensive and scientific, and build in that, and put a prohibitive tax upon dressings. We should soon then see, as Mr Street has put, by men's work what is in them.

CONDITIONS WHICH DETERMINE AND AFFECT THE DEVELOPMENT OF FORCE FROM EXPLOSIVE AGENTS.

Proceedings of the Institution of Civil Engineers.

The degree of rapidity with which an explosive substance undergoes metamorphosis, as also the nature and results of such change, are, in the greater number of instances, susceptible of several modifications by variation of the circumstances under which the conditions essential to chemical change are fulfilled.

Excellent illustrations of the modes by which such modifications may be brought about are furnished by gun-cotton, which may be made to burn very slowly, almost without flame; to inflame with great rapidity, but without development of great explosive force; or to exercise a violent destructive action, according as the mode

of applying heat, the circumstances attending such application of heat, and the mechanical condition of the explosive agent, are modified.

The character of explosion and the mechanical force developed, within given periods, by the metamorphosis of explosive mixtures such as gunpowder, is similarly subject to modifications; and even the most violent explosive compounds known (the mercury and silver fulminates, and the chloride and iodide of nitrogen) behave in very different ways, under the operation of heat or other disturbing influences according to the circumstances which attend the metamorphosis of the explosive agent (*e. g.*, the position of the source of heat with reference to the mass of the substance to be exploded, or the extent of initial resistance opposed to the escape of the products of explosion). Thus, chloride of nitrogen, when covered with even a thin film of water, explodes with great violence when brought into contact with a decomposing agent; but if the covering of water is entirely removed, and the usual means are resorted to for causing the instantaneous decomposition of the liquid, its transformation into gases takes place with little or no explosive violence. Again, if a heap of fulminate of mercury be ignited at any portion of the exposed surface or immediately beneath it, the substance inflames with a dull explosion, and but little mechanical work is performed; but if the heap be ignited in the centre, or near the base, the explosion is very violent, and considerable shattering effect is produced. In these instances, the covering of the water, on the one hand, and the external portions of the heap of fulminate, on the other, perform the functions of the tamping in a blast-hole, or of the walls of a shell, in determining accumulation of pressure and consequent development of violent explosion at the point of first ignition, which is then instantaneously transmitted throughout the mass. Applying this result to practical purposes, it is found that by igniting a charge of powder at or near the base in an ordinary blast-hole, considerable destructive effect can be developed without the use of any tamping, as the upper portion of the charge acts itself as tamping to the part first ignited, and develops its violent explosion. The destructive action is, of course, still further increased if tamping be employed under the above conditions.

Nitroglycerine and analogous explosive compounds, which bear some resemblance to chloride of nitrogen in their power of sudden explosion, require the fulfilment of special conditions for the development of their explosive force. Thus, the explosion of nitroglycerine by the simple application of heat can only be accomplished if the source of heat be applied in such a way that chemical decomposition is established in some portion of the mass, and is favored by the continued application of heat to that part. Under these circumstances, the chemical change proceeds with rapidly accelerating violence, and the sudden transformation, into gaseous products, of the heated portion eventually results—a transformation which is instantly communicated throughout the mass, so that confinement of the substance is not necessary to develop its full explosive force.

The same result can be obtained more expeditiously, and with much greater certainty, by exposing the substance to the concussive action of a detonation produced by the ignition of a small quantity of fulminating powder, closely confined and placed in contact with, or in proximity to, the explosive compound.

The development of the violent explosive action of nitroglycerine, freely exposed to air, through the agency of a detonation, was for some time regarded as a peculiarity of that substance; it has, however, been demonstrated that gun-cotton and other explosive compounds and mixtures do not necessarily require confinement for the full development of their explosive force, but that this result is attainable (and very readily in some instances, especially in the case of gun-cotton) by means similar to those applied in the case of nitroglycerine.

The manner in which a detonation operates in determining the violent explosion of gun-cotton, nitroglycerine, etc., has been made the subject of careful investigation. It has been demonstrated experimentally, that the result cannot be ascribed to the direct operation of the heat developed by the chemical changes of the charge of detonating material used as the exploding agent. An experimental comparison of the mechanical force exerted by different explosive compounds, and by the same compound employed in different ways, has shown that the remarkable power possessed by the explosion of small quantities of certain bodies (the mercury and silver fulmi-

nates) to accomplish the detonation of gun-cotton, while comparatively large quantities of other highly explosive agents are incapable of producing that result, is generally accounted for satisfactorily by the difference in the amount of force suddenly brought to bear in the different instances upon some portion of the mass operated upon. Most generally, therefore, the degree of facility with which the detonation of a substance will develop similar change in a neighboring explosive substance may be regarded as proportionate to the amount of force developed within the shortest period of time by that detonation; the latter being, in fact, analogous in its operation to that of a blow from a hammer, or of the impact of a projectile.

Several remarkable results of an exceptional character have, however, been obtained, which indicate that the development of explosive force under the circumstances referred to, is not always simply ascribable to the sudden operation of mechanical force. These were especially observed in the course of a comparison of the conditions essential to the detonation of gun-cotton and of nitroglycerine by means of particular explosive agents (chloride of nitrogen, etc), as well as in an examination into the effects produced upon each other by the detonation of these two substances. In illustration, it may be instructive to give two examples. The detonation of compressed gun-cotton is accomplished by the explosion of 5 grains of confined fulminate of mercury, placed in contact with the mass, but it requires ten times that quantity of the violent explosive agent, chloride of nitrogen, also confined, to produce the same result. Again, the mechanical force exerted by the explosion of nitroglycerine is fully equal to that developed by the fulminate of mercury, yet a quantity of nitroglycerine, about seventy times greater than the minimum of the fulminate required to detonate compressed gun-cotton, fails, when exploded in contact with the latter, to produce any other result than the complete mechanical disintegration of the mass.

The explanation offered of these exceptional results is to the effect that the vibrations attendant upon a particular explosion, if synchronous with those which would result from the explosion of a neighboring substance in a state of high chemical tension, will, by their tendency to develop those vibrations, either determine the explosion of that substance, or at any rate greatly aid the disturbing effect of mechanical force suddenly applied; while, in the instance of another explosion, which develops vibratory impulses of different character, the mechanical force applied through its agency has to operate with little or no aid; greater force, or a more powerful detonation, being therefore required in the latter instance to accomplish the same result.

Instances of the apparently simultaneous explosion of numerous distinct and even somewhat widely separated masses of explosive substances (such as simultaneous explosions in several distinct buildings at powder-mills) do not unfrequently occur, in which the generation of a disruptive impulse by the first, or initiative explosion, which is communicated with extreme rapidity to contiguous masses of the same nature, appears much more likely to be the operating cause, than that such simultaneous explosions should be brought about by the direct action of heat and mechanical force.

With regard to the general manner in which a detonative action determines the violent explosion or sudden chemical disintegration of such a substance as gun-cotton, the similarity of its operation to that of a blow is readily demonstrated by many and simple experiments; one or two may be mentioned, which have been made with gun-cotton, and which probably illustrate the subject sufficiently for present purposes. The heat developed in a mass, when submitted to a blow, depends upon the resistance which its particles oppose (by reason of its rigidity or solidity) to the motion of the body striking it. Repeated blows may be required to explode a detonating substance placed in the form of loose powder upon an anvil; that force being, at first, in part expended in compressing the particles into a compact mass. When no longer free to move, the resistance they oppose to the force applied determines the sudden transformation of the latter into heat to a sufficient extent to bring about the detonation of the substance struck. If, in the case of gun-cotton, the force developed by a detonation, even of a powerful character, is allowed to operate upon the material in a loose, flocculent condition, the latter is simply dispersed; again, if the gun-cotton be only lightly compressed, a much more powerful detonation is required for its explosion than if it

be in a very compact condition; and if the mass of the highly-compressed material be only very small, it cannot be detonated by the means which are successful with larger masses, unless special precaution be taken, by fixing it rigidly to the detonating fuze, to prevent its being dispersed by the force which the explosion of the latter exerts. These facts, when compared with the following experiments, demonstrate that the general action of a detonation in developing the violent explosion of the substance upon which it is allowed to operate is that of a sudden blow given to some portion of a mass, the particles of which are in a condition to resist the motive or dispersive power of the mechanical force applied. A bullet from a Martini-Henry rifle was fired at a distance of about 50 yards against a slab of compressed gun-cotton 0.75 in. thick and 3.75 in. in diameter (weighing four ounces), freely suspended in air by a string; the gun-cotton was simply perforated by the bullet.

A similar result was several times obtained with slabs of gun-cotton of the same dimensions, and with others double the thickness. On making the experiment with a slab of three times the thickness, the gun-cotton was inflamed but not detonated by the impact of the bullet. The mass was in this instance of sufficient thickness to offer considerable resistance to the penetrative power of the bullet; the passage of the latter was therefore retarded to such an extent as to give rise to the heating of the opposing gun-cotton particles up to their inflaming point. This experiment was repeated with the same result; but when a bullet was fired against a piece of compressed gun-cotton four times the thickness of that first employed, and weighing one pound, the result was detonation of the mass.

It need scarcely be stated that the detonation of a large quantity of an explosive body is accomplished by the initiative detonation of a very small portion of the mass; this is the case even if the material is arranged in the form of a train of considerable length, the detonating fuze being applied at one extremity. Rows of gun-cotton disks, from 3 to 5 ft. in length, with intervals of 0.5 in. and 1 in. between the individual masses, have been detonated in this way. There is, however, a limit to the distance to which a detonation will be transmitted along a row of spaced disks, the limit being determined by the particular weight of the masses employed; if it be exceeded, those masses which are at the farther extremity will be inflamed and scattered, instead of being detonated. A few preliminary experiments have been made with the view of determining, by means of Noble's chronoscope, the rapidity with which detonation progresses along a row of gun-cotton disks. This will, no doubt, vary with the sizes of the masses. In an experiment with disks weighing two ounces each, placed in a row without intervals, it was found that the detonation extended to 3 ft. in about one five-thousandth part of a second.

THE DISINTGERATION AND UTILIZATION OF SLAG.

By C. CLAUS.

From "Iron."

After the discussion on the above subject, which lately took place at the Cleveland Institution of Engineers, the Secretary received a very interesting letter from M. C. Claus, from which we extract the following:

The application of slag as a manure has been proposed, and even patented repeatedly, a long time since, and especially at a time when the chemical rationale of its value and use as such was least understood. Practical results of its application alone must, therefore, have given rise to this suggestion. The large percentage of lime seems to have been considered the active principle of its efficacy. Mr. Wood himself, even in his former paper, read before another Society, stated that on account of the large quantity of lime the slag contained, it must be considered of great value as a manure, and in a paper shown to me by Mr. Wood, since the reading of his paper, Dr. Volkner, the consulting chemist to the Royal Agricultural Society, is made to say that slag appeared to be a good substitute for lime as manure.

Believing, as I do, to have been instrumental in directing Mr. Wood's attention,

previous to the reading of his last paper, to the real source of value of slag as a manure, viz., to the silica in its readily soluble, and for plants, easily assimilative form, I feel bound to second the statements made by him in that sense.

In doing so I shall attach my remarks on the subject to the assertion by Mr. Gjers, that soil already containing 60 per cent. of silica required, not the addition of another silicious substance like slag (containing only 38 per cent.) as a manure. I beg to state that there is, perhaps, no soil more needy of silica, in the form in which it exists in slag, than a soil consisting of pure quartz sand, and containing, we will say, for the sake of illustration, 100 per cent. of silica.

Not any more logically than that a bag full of silica, clay, lime, and soda, constitutes so many dozen of glass bottles, does it follow that the existence of 66 per cent. of silica in soil is sufficient for the nourishment of plants. There are several forms of silica, some of which (such as pure quartz sand) are utterly unavailable to plants as a source of silica. Silica in its form as free silica, even in its gelatinous and otherwise soluble state, seems to be of little service to plants. Only when in combination with bases (especially lime, alumina, and potash) separable therefrom by weak acids, seems to be the form in which plants can take it up. Amongst its combination with bases, there are only a few which are readily available for plants, owing to their not being easily decomposed by highly diluted aqueous solutions of carbonic acid, and perhaps of carbonate of ammonia (the products of the decomposition of animal and vegetable matter). There is also a most remarkable difference in the degree of solubility of silicates of equal compositions in the above named re-agents—some are utterly insoluble therein, whilst others are. Others again, some clays, for instance, at first little soluble in highly diluted acid, when mixed with cream of lime, thicken, and are found to become much more soluble after such treatment; hence the explanation of the utility of burnt lime, as a manurial agent. Burnt lime is not so much a manure in itself (for there is plenty of carbonate of lime in most soils), as in acting by dissolving and opening out to the use of plants the silica, in combination with alumina, and the alkalies.

Plants containing in their ashes and requiring for their growth large quantities of silica, cannot be grown successively in the same field. The land has to be laid in fallow, in order to accumulate the amount of soluble silica, as the process of dissolving it, being in the ordinary course of things a very slow one, does not keep pace with the requirements of the plants which take up other mineral constituents in the meantime much more quickly.

Lands, otherwise well manured, but deficient in soluble silica, will grow, for instance, good and rich-looking crops of wheat, with even well-filled ears, but the straw is too weak to bear up the ear, and it therefore lies down on the ground. A remarkable instance of this was shown to me by a farmer in Yorkshire, about twelve years ago. A rich-looking field of corn in full ear was all laid down on the ground. In the midst of this stood a square patch of equally rich-looking corn, perfectly erect. The straw of the latter was found to be richer in silica than that of the former. This peculiar occurrence could not at first be accounted for, but on closer inquiry it turned out that two years previously a clamp of bricks had been burned on the spot. When silicates are intimately mixed with lime or alkalies and then submitted to the action of a strong heat, a change takes place in the condition of the silica—it enters into that condition which makes it more quickly available for plants. This is exactly what had taken place with the soil on which the brick clamp had stood, and in the Middlesborough slag we have this action to perfection.

Liebig, who was the first to show the importance of the part played by silica, in this soluble form, for the economy of plants, says, in one of his works (I forget in which), that the time may come when the agriculturists will import as a manure the mineral "Palagonite" from Iceland, in the composition of which the silica is held in so loose a state of combination that it will readily become separated even by weak organic acids. In this respect it resembles closely Cleveland slag, which also gelatinizes easily with weak acids. But our slag has, besides this chemical property, most valuable physical qualities, which especially fit it for a manure, and these it obtains when it becomes disintegrated by being run into water whilst in a fluid state As Mr. Wood stated, it becomes thereby converted into a mass of finely walled hol-

low cells, which offer innumerable points of attack to the plants feeding upon it. I consider it, for this reason, a most valuable silicious manure applicable for almost every kind of soil, and it is my opinion, that by the proper use of it, consecutive crops of wheat could be grown, year after year, on the same land, provided the other supplementary manures are supplied abundantly as well.

I recommended the spongy water-disintegrated slag two or three years ago, to a firm of owners of sugar plantations for their use, after having been consulted by one of the persons connected with the firm as to the possible cause of disease in the cane, which had shown itself to be steadily on the increase during the last few years. The sugar-cane requires large quantities of silica for its growth, and it has been the practice for years past to burn the spent cane as fuel, and to waste the ashes. The land had thus become so impoverished of assimilative silica, that it no longer did its duty. I am sorry to say they did not avail themselves of my recommendation, else Middlesborough might now be doing a good trade in slag with the West Indies.

The exceedingly porous form of the water-run slag offers other conditions favorable to the subtle agencies at work in the growth of plants.

Allow me, in conclusion and self-defence, to say a word or two in reference to the statement made by Mr. Wood, when showing the specimens of tiles and slabs made by my patent process from the slag. He said they were splendid specimens, which compliment I will receive with thanks, but he said also that the process of manufacture was expensive. Considering that the materials and operations connected therewith are so much like those in the process by which he says that bricks can be made for 12*s.* per 1000, I cannot see where he can find the source of expense. I mix disintegrated slag with about 20 per cent. of common brick clay intimately, mould the mass in a brick machine or by hand into bricks, and, if pressed goods are wanted, press them, then dry for two or three days, and burn them. In the Slag Working Company's process, they mix intimately disintegrated slag with lime (instead of my brick clay), mould and press, and then dry in the air for two or three weeks. Where now is the difference in cost, except in the burning? As offset against this, I have common clay against their lime.

THE INFLUENCE OF ACIDS ON IRON AND STEEL.*

From "The English Mechanic and World of Science."

He said Professor Reynolds, in an interesting paper "On the Effect of Acid on the Interior of Iron Wire," appears to think that I did not attribute to hydrogen any portion of the remarkable change produced in iron and steel by immersion in acid. That immersion in acid is the primary cause no one, I think, will dispute; but that hydrogen plays an important part in producing these changes and is the cause of the bubbles, the following paragraph from a paper I read before the Society, March 4th, 1873, will prove: "The experiments of Professor Graham in 1867, and more recently those of Mr. Parry, show that hydrogen, carbonic oxide and carbonic acid, and nitrogen are evolved from wrought iron, cast iron, and steel when heated in vacuo. Therefore it seems probable that a part of the hydrogen produced by the action of the acid on the iron may be absorbed by the iron, its nascent state facilitating this. And when the iron is heated by the effort of breaking it, the gas may bubble up through the moisture on the fracture." The supposition that the absorption of hydrogen is the sole cause of the change in the breaking strain, diminution in toughness, etc., attendant on the immersion of iron hydrochloric or sulphuric acids, and that there is no absorption of these acids into the interior of the iron, does not account for the following phenomena:—1. The gain in weight of a piece of iron by immersion in hydrochloric acid is less than by immersion in sulphuric acid, as is proved by experiments described in my first paper on this subject. 2. Iron after immersion in hydrochloric acid sooner regains its original state than after immersion in sulphuric acid. 3. If acid iron, *i. e.*

* A paper read before the Manchester Philosophical Society by W. H. Johnson.

iron which has been immersed in hydrochloric or sulphuric acid, be steeped in an alkaline solution it sooner regains its original state than with immersion in water alone. 4. Take two pieces of iron alike in size and quality, and immerse one in hydrochloric acid and the other in sulphuric acid for some hours, then wash them well in water and dry them gently, and leave them in a temperate room for some hours more. At the end of that time it will be invariably found that the piece which was in hydrochloric acid is covered with a dark-brown red oxide of iron, while the piece which was in sulphuric acid will be only slightly rusted. 5. Litmus paper when applied to the moistened fracture of acid iron is slightly reddened. All the above phenomena have been observed so often and so carefully as to leave no doubt of their invariable recurrence if the conditions of experiment be only properly observed. It seems to me that the only satisfactory way of explaining all the phenomena is to suppose that when a piece of iron is immersed in acid two actions go on, viz., an absorption of the nascent hydrogen into the interior of the iron, which hydrogen may subsequently be given off by gentle heat or immersion in a liquid, etc.; secondly, an absorption of the acid itself, possibly in a very concentrated form, by the insterstices between the fibres or crystals of the metal. That it is possible for a liquid to pass into the interior of a piece of iron is, I think, proved by the sweating of the cylinders of hydraulic presses, and also the known diffusion of gases through iron.

The structure of iron as revealed by the microscope and the changes it undergoes during manufacture, by which a spongy mass is by hammering and rolling squeezed together, all go on to prove that there are numerous cavities in iron and steel. It will, however, be said the acid must act on the walls of the cavity and form a salt of iron with liberation of hydrogen. This may go on to a small extent, but in opposition to this view we may bring the experiments of Professor Bequerel on solutions separated by a cracked tube ("Comptes Rendus," LXXVI.), where he shows that no precipitate is formed on placing a cracked tube filled with nitrate of lead in a solution of potassium sulphate within the crack, thus making it probable that chemical interchanges do not take place in very minute spaces. By this theory we may easily explain the decrease in toughness after immersion in acid, for toughness implies a certain ease of mobility of the particles. When a piece of iron is bent, the particles of one side are compressed, thus diminishing the minute cavities between the fibres; while those of the other side are stretched, and the minute cavities elongated. Now if we fill these cavities with a liquid, this mobility of the particles is prevented, for the cavities cannot now be diminished in size, and the compression of the one side cannot now take place; consequently the piece tears or breaks off just like a piece of frozen rope. It will also explain the acid reaction of the moistened fracture; and further, as hydrochloric acid is much more volatile and of less specific gravity than sulphuric acid, it is only natural to expect that the effect of immersion in hydrochloric acid will pass off more rapidly than of immersion in sulphuric. This, experience fully confirms. With a view of determining these interesting points a number of experiments were made in the following way, viz.:—Small coils of iron wire were immersed in hydrochloric and sulphuric acids for different lengths of time, and then carefully tested for tensile strain in a very accurate machine, so constructed that the elongation of the wire while under strain could at any moment be ascertained. The weights could also be added quickly and without imparting any shock to the wires, points to which great importance should always be attached in experiments of this kind, as a slight shock or jar on the addition of a weight will often cause the rupture of a piece which otherwise would have stood a much higher strain. The length of the pieces tested was in all experiments 10 in. between the dies of the machine, and their temperature at the time of experiment about 16 deg. C. After the ultimate elongation and breaking weight had been ascertained with this machine, the coils were placed on warm plates or in hot chambers for some hours, and subsequently tested in the same way.

Experiments were made in this way, and lead us to the following conclusions:—1. That immersion in hydrochloric acid for one hour diminishes the tensile strain of annealed iron 297 lbs. per sq. in. of section; the tensile strain of unannealed iron 2,389 lbs. per sq. in. of section, and diminishes the ultimate elongation of annealed iron 0.8 per cent.; ditto, unannealed iron,

0.38 per cent. 2. That immersion in hydrochloric acid for six hours diminishes the tensile strain of annealed mild steel 2,563 lbs. per sq. in. of section, and increases the ultimate elongation of annealed mild steel 4.7 per cent. When first I discovered that a decrease of ultimate elongation under strain was the result of immersion of steel in acid, I thought there must be some experimental error, and accordingly carefully selected three coils, all of uniform temper, and made three tests from each coil. The singular regularity of these tests must be said to remove all doubt as to the truth of the results of the first experiment. It then occurred to me that possibly prolonged immersion in acid might so decrease the breaking strain that the wire would not recover its original strength. For this purpose I carefully tested the elongation and breaking strain of the wire before immersion in acid, and again after heating for five days on a hot plate. The results of these experiments confirm this view, showing that there is—1. A permanent decrease in breaking strain after prolonged immersion in sulphuric acid, of 12,205 lbs. per sq. in. of section; hydrochloric acid, of 31,275 lbs.

Both these results are, doubtless, too high, as the surface of the wire was pitted by the acid; consequently its actual sectional area was less than that calculated from the diameter as measured. 2. A permanent increase in the elongation after prolonged immersion in sulphuric acid of 1.7 per cent., hydrochloric acid of 1.17 per cent. Having examined the effect of acid on annealed steel, it was next thought advisable to try the effect on unannealed. This showed that the immediate effect of immersion in acid was to decrease the tensile strain of unannealed steel 4,045 lbs. per sq. in. of section, and increase the ultimate elongation of unannealed steel 2.14 per cent. The change is thus similar to that which takes place in annealed steel. It is, however, interesting to observe that 12 hours at a temperature of 40 deg. to 100 deg. C. not only restores, but actually increases, its original breaking strain and elongation, while a still more prolonged submersion of 7 days to the same temperature still further increases them. These last experiments also show that some considerable time is required to overcome the change produced by the acid. In conclusion, I may say that the numerical results arrived at, though based on experiments conducted with considerable care, must not be taken as more than approximations to the truth, for experimental errors and variations arising from the imperfect homogeneity of structure of all iron falsify the results, and are only lost by multiplying experiments almost indefinitely.

THE PNEUMATIC PROCESS OF SINKING PILES.

By JOHN W. GLENN, C. E.

Written for Van Nostrand's Magazine.

In the April number of Van Nostrand's Magazine, page 361, Mr. Gabriel Jordan, C. E., states: "During the late war between the States, the Confederate Engineer successfully used the process in sinking heavy wooden piles in the Bay of Mobile.

"In many instances these piles were driven 10 and 15 feet in the short space of one minute, through a material that could not be penetrated by piles driven in the usual way."

It was in 1862 that the work referred to was done; and as the method and details of it were proposed by me, and carried out under my personal supervision, probably a description of it, its causes and purposes, will be interesting to the profession.

Then a Lieutenant of Engineers, I was assigned by Gen. Leadbetter, Chief Engineer, to the charge of the outer line of water defences of Mobile Bay, which then consisted of only Forts Morgan and Gaines, both of which were incomplete and incapable of either offering serious opposition to a properly equipped fleet, or of maintaining a siege.

In the work to be then done so that, as far as practicable, Mobile Bay might be sealed against outsiders, that part of the line which presented apparently the greatest difficulties, was the middle ground between Forts Morgan and Gaines, beginning on the west side of the ship channel, thence to Fort Gaines, about two miles.

On this middle ground was an average depth of about 8 feet of water, with a mean rise and fall of the tide of about 18 inches.

This depth of water was sufficient to allow formidable gunboats to enter the bay, to which the two forts, being three miles apart, could offer little opposition, unless the vessels could be retained under fire a sufficient time to give the gunners of the forts their range, and make their fire effective.

The only method my superiors in rank then would consider was obstruction, and as the place to be obstructed was the outlet to that great bay, exposed to every swell of the Gulf of Mexico, through which the tides swept with a current of about three miles per hour, they were sceptical as to the practicability of almost any method, and at one time they had adopted the policy of quietly removing the munitions and surplus guns, reducing the garrisons to a minimum, merely to keep up a show of resisttance.

After making a careful examination of the middle ground, I found it for a depth of over 20 feet, except near Fort Gaines, to be a deposit of sand, such as is common to the Gulf coast.

The violence of the storms, insufficiency of the sand as holding ground for anchorage, and the scour it was liable to, rendered chain-booms, cribs, and all usual methods of obstructing, out of the question.

As the bottoms of all war vessels then afloat were wood, it occurred to me that if ten (10) rows of sawyers, none less than 18 inches in diameter, 10 feet apart in each row, the sawyers of one row opposite the intervals of the next, were planted in that sand, not less than 12 feet deep nor more than 20, and then sawed off below the water so as to leave the stumps projecting above the bottom alternately 3 and 4 feet, that if a vessel was to endeavor to drive its way through the 10 rows, it would find itself "piled up" on the stumps with perhaps one or more through the bottom, or, in case of the forcible removal of the sawyers being attempted, the time required would be sufficient to enable the gunners of the forts to disable the vessel attempting it.

At the time, and considering the great width and depth of the ship channel next to Fort Morgan, it was believed that the displacement of water, and opposition to currents offered by the sawyers, would not produce observable results, but the Pelican Island channel, next to Fort Gaines, was, after the sawyers were planted, found to have scoured nearly two feet deeper.

Owing to the attacks of the "Teredo Na Valis," the sawyers would not have constituted an obstruction over one year, but when the limit of usefulness of one system was reached, another could be planted.

I submitted my views, togther with the description of the manner of planting the sawyers by pneumatic pressure, and, in order to carry on the work expeditiously, asked for two steamers—the two steam fire engines of the city of Mobile, with complements of firemen, teams, and laborers, to procure the sawyers from Dauphine Island, adjacent to the work.

The steamers Dick Keys and Natchez were selected. Amidships, and just after the boilers on each steamer, a steam fire engine was placed, and bolted to the deck.

The steam-chest of the steam fire engine was connected directly with the boilers of the vessel by an inch pipe, and communication with its own boiler broken.

Small shears were erected amidships, which lead outboard sufficient to clear the vessel. From their head was suspended five pulley blocks and falls, for handling the sawyers.

About 50 ft. of hose and an ordinary 1¼ in. fire nozzle were attached to the air chamber, while the suction hose was passed out into the sea water. Each steamer would take on deck from twenty to fifty sawyers, varying from 18 to 30 in. in diameter, generally; though in one instance one of 48 in. in diameter was planted, and a great many between that and 30 in.

The ebb tide, at its greatest velocity, was selected as the time to make the beginning, and the Natchez was brought to anchor on the ground with about 100 fathoms of chain out and a kedge off her starboard quarter, with about 50 fathoms of 5 in. hawser out.

A sawyer was now swung by it, head to the shears; at its lower end two iron staples were driven, in which the brass nozzle was placed, and from the point of the nozzle, and outside the staples, a strand of tarred yarn led to the hands of the director, who controlled the movements of the engine, etc. The sawyer now hung suspended from the shears; a sufficient number of men had hold of the falls to control the

sawyer; the director had hold of the yarn, with which he kept the nozzle in the staples, and the engineer stood at the engine, ready to start it when directed.

By the after capstan the hawser was now heaved in sufficient to bring the steamer quartering to the current which brought the chain and hawser both taut for a minute, perhaps. The instant the vessel settled, the steam fire engine was started, and as soon as a stream of water began to flow through the nozzle, the sawyer was lowered and settled in the sand at the rate of about one foot per second. When the requisite depth was attained, the director let go the yarn, seized the hose and pulled its nozzle; the engine was stopped, and by this time the sand had settled to within two feet of its original surface, and the sawyer was immovable.

After the first five sawyers were planted the steamers were moored to them, and, guided by them, moved ahead in the line of the work. After the first day or two the men became so adept that the work progressed very rapidly, even when there was a light swell on.

Over (5,000) five thousand sawyers were in that manner planted, when I was transferred to more important duties in the field.

The machinery and arrangements were the best obtainable in a country then cut off from the balance of the world; not by any means the best, with time and abundant resources for preparation.

The application of pneumatic pressure to sea-coast work first took definite shape with me in 1853, and was first applied by me in 1855, and I expect, eventually, to see it become a leading feature in preparation and giving fixedness to jetties, which must ultimately exercise great influence upon the shallow entrances to our Gulf harbors, the prominent features of which are this same sand.

WHAT IS FIRE-PROOF CONSTRUCTION?

From "The Building News."

The heavy losses recently sustained by a large number of individuals among the "upper ten thousand" by the disastrous conflagration in Belgravia has directed public attention to the discussion of the subject of fire-proof construction, and has led many to doubt whether it is possible to erect a large building capable of resisting the ravages of fire. And this doubt is almost converted into a certainty when they discover that most of the great fires which have occurred within recent times have been in buildings designated "fire-proof." The extensive warehouses in Tooley street, which were destroyed by fire in June, 1861, and in endeavoring to extinguish which Mr. Braidwood lost his life, were constructed on what are termed "fire-proof" principles—namely, with floors formed of brick arches upon iron girders and iron columns. Yet we find that these warehouses, extending over three acres of ground, and containing goods valued at over two millions sterling, were as entirely destroyed as if they had been built of wood. More recently has occurred the destruction of the City Flour Mills, in November, 1872, in which the floors were of stone flags laid on iron joists, resting upon iron girders, and supported by iron columns—a mode of construction which was thought to be perfectly fire-proof, since no part of it could burn. We have also seen how the "fire-proof" construction failed at Paris, in 1871, when the Communists burnt down a large portion of that city. We have, therefore, placed before us the serious question, and one that it behooves an architect to be able to answer satisfactorily—namely, What is fire-proof construction?

There appears to be in the minds of most ordinary persons, and indeed of many practical men, a considerable amount of confusion between materials that are incombustible, and those which are fire-proof. The former term is applicable to all materials which will not take fire or blaze up when subjected to great heat, or which can never be made to act as additional fuel to the flames—such as stone, brick, concrete, iron, cement, plaster, tile, slate, glass, and several hard woods. Only a few, however, of these can be properly called fire-proof, or capable of resisting without change the action of intense heat. Among the great variety of building stones but few can be considered fire-proof; limestones are readily calcined and converted into quicklime by

the action of fire, so that Portland stone staircases are considered by London firemen as far more dangerous than ordinary wooden ones, as they snap off and fall in a mass as soon as the flames touch them. Yorkshire flagstones will split to pieces by the action of fire; but there are many good building stones in Yorkshire, called by geologists the "grits," which are capable of withstanding great heat. These are, however, comparatively little known to London architects. There are also the grits of Scotland, such as Cragleith stone, and many others which may be considered as fire-proof. Granites are not so fire-resisting as their igneous origin would lead us to expect; but they are capable of withstanding a considerable heat unless suddenly acted upon when hot by a jet of water. There are several kinds of artificial stone now made which are far more fire-proof than most of the natural stones. Concrete may be considered as an artificial stone; but if made with broken limestone it will not be fire-proof; the materials used with the cement must be either sandstone pebbles, such as are found in gravel, flints, broken brick, or burnt clay. Slates are not by any means fire-proof, as they split to pieces under the action of fire. All the harder kinds of brick and tile may be generally considered as capable of resisting fire when used as walls, or as arched floors; but the softer kinds crumble when highly heated, especially if water should happen to touch them. Bricks made of fire-clay are the best that can be used in forming fire-proof structures. Iron becomes so much weakened when highly heated that it can hardly be looked upon as fire-proof, unless protected by some non-conducting substance; it is found, however, that solid cast-iron columns will stand heat far better than hollow ones, and as they take up less room, they might easily be protected by a coating of cement or other material, without occupying more space than hollow columns of the same strength would do. Cast-iron girders soon give way if heated and then cooled by a jet of water, and wrought-iron beams twist and thrust out or pull down the walls, so that unless well protected they must never be used in buildings professing to be fire-proof. Although glass cannot be made to take fire, yet it breaks into pieces as soon as the heat reaches it, and liquefies at a moderate temperature.

Hence it appears that the number of materials for construction which may be considered fire-proof is very limited, and that it depends in a great degree upon the manner in which these are used whether the building is fire-proof or not. Many of the harder kinds of timber, if used in large scantling, may be considered as fire resisting; the effect of heat does not penetrate into the interior of the wood, and only chars the outside; but when timber is cut up into thin slices as joists or rafters, it readily ignites, and adds fuel to the fire.

We will now consider what are the best modes of employing the few materials which are really fire-proof in the construction of buildings so as to render a great conflagration almost impossible. In the first place, we must look at the purposes to which a building is to be applied, as the same construction may be perfectly fire-proof in one kind of edifice but not in another. The construction of S. Thomas's hospital, for instance, with iron girders and concrete arches for the floors and ceilings, is thoroughly fire-proof, so long as it is used only as an hospital; but suppose it should at any future time be converted into a warehouse for the storage of such inflammable articles as jute, cotton, oil, tallow, or saltpetre, as was the case in the great "fire-proof" warehouses in Tooley street burnt down in 1861, there is hardly a doubt that if a fire broke out in any part the total destruction of the whole block would be inevitable. We might say the same of the handsome banking house recently illustrated in our pages, in which a similar construction is employed; and as there is no great amount of inflammable material in either building as at present used, no very great heat would be produced if a fire did occur in any one part; hence it is clear that both these edifices may be deemed practically fire-proof, except under extraordinary circumstances such as occurred at the fires caused by the Communists in Paris in 1871. Ordinary dwellings may be rendered sufficiently fire-proof at moderate expense by avoiding the use of materials that readily catch fire, such as thin joists and rafters, and light balusters to the staircases; by putting thick joists to carry the floors and pugging between them; by filling up the space under the staircase, between the wooden treads and the plaster soffit; by using iron balusters to the stairs; avoiding quarter-partitions or

having them bricknogged, so as to leave no hollow spaces; by having the floor-boards of wainscot instead of deal, and tongued with iron. A very good fire-proof floor can be made by filling between the joists with cement concrete 3 or 4 in. thick, so that the plaster can be laid on the under side without laths, and any sort of floor laid above.

But it is not in buildings of the class we have named that the great fires occur, and which can be rendered practically fire-proof without much difficulty or expense; but in the large warehouses covering acres or even miles of ground in our docks and along our river sides, and in which thousands of tons of inflammable goods are stored. These buildings require a very different mode of construction to render them capable of withstanding the tremendous heat that will be generated if a fire occurs in one of their great rooms. In the first place, the walls of such buildings ought to be made much thicker than the minimum allowed by the Building Act; an extra half-brick or whole brick in thickness would not add much to the cost, and would increase the stability to a very great degree. The brick-work should be protected both inside and outside with cement or plaster materials, which were found in nearly all cases to remain uninjured in the buildings destroyed in Paris in 1871.

Concrete would be a better material than brick for the walls of warehouses, and need not be made so thick as would be required for brick walls, being about one-third or one-fourth stronger; it should, however, have plenty of iron hooping as bond throughout it, so as to prevent settlements and cracks; when this material is used internal plastering becomes unnecessary. Concrete should also be used for the stair-cases and landings, iron hooping or wire being used to prevent risk of fracture, the steps cast in moulds and built into the walls on both sides, and not made to hang over on the outer side, as is so frequently done. If stone is, however, used for stairs, it should be one of the hard "grits" mentioned above, and free from laminations. Steps may also be made of fire-clay, terra-cotta, or artificial stone, which are both durable and fire-resisting.

For warehouses of large size it is almost impossible to dispense entirely with the use of iron girders to carry the floors; but these must be entirely covered up and protected so as to prevent the fire, should it occur, from touching them. A good way to do this is to lay concrete a few inches thick flush with the underside of the girders, and then cover the whole with common plaster; the floor above can then be laid in any way that is most convenient, as the concrete below will effectually stop any fire from passing through; the concrete should have iron hooping or wire bedded in it. If it be found necessary to support the girders in the middle, hollow iron pillars must be avoided, and they must be either of solid cast-iron or, what would be much better, of fire-bricks moulded circular and built up into a round pillar. If cast-iron is used for the pillars, it should be protected by a covering of fire-brick, concrete, or plaster. The ceiling of the top story should always be made fire-proof, and independent of the roof over it, which may then be made of any ordinary material; for even if the roof took fire, it would not be communicated to the floor below provided a fire-proof ceiling intervened. This is a point that cannot be too strongly insisted upon, as it is generally from the falling-in of the roof that the total destruction of the building follows. The iron girders which carry the floors should not be built into the wall, which is weakened by so doing, but rather supported on corbels of fire-brick or hard grit stone; in either plan, however, the ends must be allowed full play, so that in case of any expansion they may not thrust out the walls. Where an iron bressummer is introduced to carry the weight of a wall above, it must be completely protected in the manner above stated, as any twisting or yielding in the beam will endanger the whole superstructure. A casing of timber plastered over would probably be as effective a means of keeping off the heat from the iron as can be adopted.

The windows of a warehouse form an important feature, and one that must never be overlooked in considering the action of fire. If all the windows and other openings could be kept closed, a fire occurring in a room would soon burn itself out from want of a sufficient supply of oxygen; but in most warehouses there are numerous broken squares of glass which will supply air to the flames and heat up the whole room to the temperature of a blast furnace in a very short space of time. It is useless to have the frames and sash-bars of iron, if the glass is continually being broken;

either very thick glass in small squares should be used, or thin sheets of talc substituted for it.

When warehouses are built in separate blocks, but having openings for communication between them, they are fitted with double iron doors having a space nearly equal to the thickness of the party wall between the two doors. The proper construction of these doors is a very important matter, and the neglect of which has been the cause of many fires extending from block to block, until the whole series are destroyed. If the doors are made of one thickness of wrought iron, that next the room in which the fire originates soon becomes red-hot, and so twisted out of its frame as to allow the flames to attack the inner door, which in its turn gets twisted, and admits the flames to the next block of building. These doors ought each to be made 2 in. or 3 in. thick, and of double sheet-iron, filled in with some non-conducting substance; the bolts of the lock should be made to shoot both ways into the frame in three places, and the frame should be built into the wall, at least, half a brick back from the face, so that the fire can have no effect upon it. If one of these doors becomes red-hot, even on the inner face, no injury will happen to the other door, beyond the scorching of one side. The heads and sills of these doors should be formed either of hard grit-stone, concrete, fire-brick, or artificial stone. Staircases must always be separated by party walls from the several rooms, and should have iron doors to close the openings from them into the warehouse. All well-holes should be built up solid from bottom to top.

Considering the great experience that has been gained from the numerous conflagrations on a large scale, both at home and abroad, we ought to be able by this time to construct buildings in such a manner that no fire can destroy them; or, at least, in which the fire can be easily confined to the single apartment in which it commences. Much has been said about having a good water supply, with hydrants all over the premises, and watchmen always at hand to extinguish the first spark of fire that may be discovered; but for our own part we place little confidence in such arrangements, as it almost invariably happens that a fire breaks out when least expected, and when either the water-supply has run short, or the watchman has been called away; and, before the appliances can be made use of, the fire has got such a hold on the premises that all the engines in London cannot put it out. With ample means at command, and an endless variety of material ready to hand, an English architect of the present day ought to find no difficulty in being more than a match for that most destructive of all elements—Fire.

THE SPEED OF UNARMORED SHIPS.

From "Engineering"

The discussion upon Mr. Barnaby's paper read last week before the Institution of Naval Architects,* contained as little of permanent value as such discussions usually do contain, but one of the opinions expressed is worth a brief examination, on account of the mischievous nature of the fallacies which underlie it. Mr. Barnaby's remarks, and his critics', upon the new armored ships, we shall consider on another occasion; for the present we will deal only with the question of speed in unarmored vessels. Of these, certain representative ships, chosen because they "promise to have some degree of permanence as types," were shortly described in the paper, the general effect of the description being to show that the navy, at least as regards its unarmored ships, is at length being built upon a definite plan. From the smallest gunboats to the largest frigates the constructive department of the navy appears at last to have made up its mind what it wants, and we may hope that the hitherto incessant variation of type—which, as Mr. Scott Russell, we think, well said, "has given us a navy but not a fleet"—will now cease to affect the unarmored portion of the navy. Mr. Barnaby's paper described three classes of small craft, with 9½ to 10¼ knot speed, viz., the Coquette class—gunboats of 408 tons displacement (295 tons, measured on the old system)—and two sizes of sloops, the Arab of 620 tons and Daring of 894 (720); a 13-knot

* Printed *in extenso* in "Engineering" of last week.

corvette of moderate size and cost, the Magicienne, of 1,864 (about 1,400) tons; and some large corvettes possessing the great speed of 15 knots, and a corresponding armament.

In this summary there is surely no suggestion of deficient speed, yet speaker after speaker rose up to rebuke the Admiralty for "going back" in the matter of speed, as though every one of the ships described were not (as we believe is the fact) materially faster than any similar vessel which has preceded it. To our mind a gunboat of 295 tons, able to steam 10¾ knots at the mile (as one of the class is said to have done), is very creditable, considering that she is also an efficient sea-going vessel, heavily armed, comparatively heavily rigged, compelled to accommodate a numerous crew, and built to stand hard knocks of all kinds. The little sloops—for both the Arab and Daring are small vessels—have also a creditable speed, considering the many calls upon their limited displacement, and we may mention that great, though we believe scarcely merited, fault has been found with one of those classes on the ground that she is "all engine room." In fact, until some great development takes place in the science of marine engineering, there is no chance of getting higher speeds from vessels of this small size, unless we are content to build a class of mere steam yachts, good for privateering operations near home, but unfit to take care of themselves at more than a day's steaming from a coaling station, or to engage with success with the smallest and slowest of gunboats, in whose design fighting efficiency has been allowed due weight. If there is really no use in 10-knot ships, we must give up building anything under the corvette class, and if nothing is worth building that cannot steam 15 knots, as half the speakers at the Institution, and so many writers in the press, appear to suppose, we must erase from the "Navy List" all but the largest and most expensive vessels, and reverse every accepted tradition of maritime warfare. Fast ships of war cannot be small, and cannot be cheap. It cannot be too often repeated that the common talk about "1,000-ton ships steaming 15 knots, and each carrying one heavy gun," etc., is nonsense of the worst description, and we can only express our surprise that Sir John Hay, an admiral and a former Lord of the Admiralty, should have thought it right, in discussing the Admiralty designs, to ask whether "any young officer present, anxious for promotion and prize money," would rather command one of the 10-knot sloops, or a "hired mercantile steamer, armed with a 64-pounder gun, and steaming 14 knots." Does Sir John Hay really suppose that mercantile steamers, small enough (*i. e.*, cheap enough) for such service, capable of steaming 14 knots, and fit to keep the sea, have any existence at all? Or does he think it would pay to charter a fleet of Sarmatians (or, say, all the Cunarders) in order to enable his young friends to make prize money? If so (and he will hardly otherwise get the speed he wants) the "hired mercantile steamers," being amply big enough, may just as well carry a dozen guns as one, and will thus appear in their true character, namely, as very imperfect, and not at all cheap copies of the Volage and Bacchante 15-knot classes in the navy—to which costly vessels we ought therefore to devote almost our whole attention. This is what all these high-speed arguments come to, little as their authors intend it, namely, let us build nothing but ships whose cost, compared with that of the largest 10-knot sloop, is nearly as 5 to 1.

Even when thus put, the argument may be defensible, but we do not think it will commend itself widely It is true, of course, that a fast war steamer will always be able to destroy or capture a small one, provided she is more heavily armed. If the armaments are equal, we see no conclusive reason why the battle should so end, simply because we do not believe in actions fought at high speeds; but as it is part of our case that the fast ship, if a war ship at all, must be larger than the other, we allow that she will have, or ought to have, greater offensive power, and thus be likely to win. This confession of the inferiority of slow ships, involves only the truism that big ships can thrash little ones, which is not a new discovery. But steam, we admit, has given it a new force. In the old days little ships could, as a rule, escape big ones. They carried more canvas in proportion to size, and though unable to fight, could run away. But with steam, size nearly always means speed; hence a little ship, once sighted by a big one, must strike to her. For this reason, we have always objected to small ironclads, as being much too costly for ships so likely to change hands, and we must allow the same objection to have

weight against small ships of any kind. Are we then to condemn the 10-knot classes?

The answer lies in the fact that men-of-war have a great deal to do besides fighting larger vessels. Our navy includes, and is obliged to include, a vast number of small ships, performing duties in peace and war, which it would be sheer waste of power to set large vessels to carry out, and which, in many cases, large vessels could not carry out at all. The process of "exhibiting the British flag," from which the British merchant appears to derive so much comfort, can be just as well done by the Arab as by the Inconstant, and Chinese pirates can be exterminated better by the Coquette than by either. The 10-knot ships are fast enough to catch merchant-men (all but the higher class of steamers), and though extemporized privateers of the Alabama kind are likely to be larger, and to command more speed, the heavy armament of the Arab and Daring, and the man-to-man superiority which the crew of a British man-of-war may be expected to show over the scratch complement of a privateer, should at least preserve from molestation. If they cannot catch the privateer, that is no reason they should be condemned, if otherwise useful. They do not profess to be privateer catchers; that function belongs to another and special class. They have duties which they fulfil satisfactorily. They can at least drive off the enemies they are likely to encounter, and if they fall in with foes of heavier metal, their capture brings neither discredit, nor loss commensurate with the good they may have done in their lifetime, upon the British flag. For these reasons we think the condemnation passed upon the 10-knot small craft is altogether mistaken, and if it is made clear that no position is claimed for them as fighting ships, that they are only held to be useful for a limited but essential service, just as despatch vessels are useful, or tugs are useful, or royal yachts are useful, or any others of the special classes which figure in the Navy List, we do not think further objection is likely to be taken to them. It was not the least merit of Mr. Barnaby's paper that it clearly laid down—we believe for the first time—this division between the gunboats and small sloops and the genuine fighting ships; but the few words in which this was done appeared to have been forgotten when the discussion took place.

The lowest class of genuine fighting ship, which is described in the paper, is represented by the Magicienne, which differs but slightly from previous vessels. Her measured-mile speed is 13 knots, which, with an armament proportioned to her size, is reckoned sufficient to make her an effective convoy, and a scourge to all privateers. In this opinion we entirely concur. No extemporized privateer will be able to escape the Magicienne, nor to stand before her. Privateers of more than 13 knots we have already implied our disbelief in, unless in exceptional localities, near the enemy's ports, where very light steamers can operate, and any such, if able to escape the Magicienne, will certainly not be in a position to attack her. At the same time we agree that 13 knots, though sufficient, is the minimum speed for this important class, and we would deprecate the creation of any intermediate type between the cheap 10-knot classes, whose capture is of small importance, and the 13-knot privateer catcher, and general protector of commerce.

The Magicienne must strike, of course, without firing a gun, to the 15-knot Bacchante, which is twice as large. To abolish the Magicienne class for this reason and substitute Bacchantes, would be impossible, for the Bacchante costs more than twice as much as the Magicienne. The class of privateer catchers must be numerous, and no nation could afford a sufficient supply of Bacchantes. These must always be few, and the Magiciennes will have a good chance of not falling in with them. It is our business, of course, to see that we have more than other people, so that when a hostile Bacchante selects a cruising ground, we may have another, or something better, to send against her. It is, no doubt, only by superiority in these costly 15-knot ships that we can keep the ultimate control of the sea, and so far the advocates of high speeds are right. But in the scheme of duties just sketched there is ample occupation for slower vessels; in fact, the 15-knot ships are required but in very small numbers—numbers which will be regulated mainly by the enemy's force of vessels stronger than our Magicienne. Happily, in this class we are not likely to come short. The Active, Volage, Rover, Bacchante, Boadicea, and Euryalus, backed by the magnificent Raleigh, Inconstant, and Shah, leave us little cause to dread rivalry in the

matter of high-speed cruisers. Besides, this is a class which every one commends, and which the Admiralty lacks no inducement to build; while its construction and management require a skill in which English dockyards and English officers need not fear to be surpassed. We have referred here to the Bacchante rather than to the Rover, which seems to us a less desirable type. The Rover, of 3,450 tons displacement, has an open gun-deck, and 64-pounder guns. The Bacchante, 500 tons larger, has a covered battery and 118-pounder guns, and the additional size (representing 10 per cent. additional cost) appears well applied. What is wanted is incontestable superiority to the Magicienne, and to everything like her. The announcement that "wooden ribs are finally doomed" we receive with hearty satisfaction. There are many reasons which account for the preference still given to wooden skins in the smaller men-of-war, and though the composite system of construction does not seem latterly to have found great favor in private yards, there is every reason to think that it will answer well in the dockyards. It has now had, in fact, some years' trial in men-of-war, and with satisfactory results. The following Table gives the leading particulars of the principal vessels mentioned by Mr. Barnaby, so far as they are described in his paper:

Vessels.	Displacement.	Tonnage (Old System).	Speed.	Guns.	Proportionate Cost.	Number of Crew.	Construction.
	tons.		knots.				
Coquette class.	408	295	9½ to 10	2 64-pr 2 20-pr	1	60	Composite coppered. Guns on upper deck.
Arab " .	620	....	10 to 10½	1 118-pr. 2 64-pr	1.9	90	
Daring " .	894	727	10 to 10½	2 118-pr. 2 64-pr.	2.25	120	
Magicienne....	1864	about 1400	13	14 64-pr.	5.4	220	
Rover..	3451	. ..	15	2 118-pr 16 64-pr.	10	320	Iron, zinc sheathed. Guns on upperdeck. Is a ram.
Bacchante.....	3932	2679	15	14 118-pr.	11	...	Iron, zinc sheathed. Guns covered. Is a ram.

THE ATTRACTIONS OF MAGNETS AND ELECTRIC CONDUCTORS.

By GEORGE GORE, F. R. S.

From "The Telegraphic Journal."

Being desirous of ascertaining whether, in the case of two parallel wires conveying electric currents, the attractions and repulsions were between the currents themselves or the substances conveying them, and believing this question had not been previously settled, I made the following experiment:—

I passed a powerful voltaic current through the thick copper wire of a large electro-magnet, and then divided it equally between two vertical pieces of thin platinum wire of equal diameter and length (about 6 or 7 centimetres), so as to make them equally white-hot, the wires being attached to two horizontal cross wires of copper.

On approaching the two vertical wires symmetrically towards the vertical face of one pole of the horizontally placed magnet, and at equal distances from it, so that the two downward currents in them might be equally acted upon by the downward and upward portions respectively of the currents which circulated round the magnet-pole, the one was strongly bent towards and the other from the pole, as was, of course, expected; but not the least sign of alteration of relative temperature of the two wires could be perceived, thereby proving that even a small proportion of the current was repulsed from the repelled wire, or drawn into the attracted one, as would have occurred had the attraction and repulsion taken place, even to a moderate degree, between the currents themselves; and I therefore conclude that the attractions and repulsions of electric conductors are not exerted between the currents them-

selves, but between the substances conveying them.

Some important consequences appear to flow from this conclusion, especially when it is considered in connection with Ampére's theory of magnetism, and with the molecular changes produced in bodies generally by electric currents and by magnetism.

As every molecular disturbance produces an electric alternation in bodies, so, conversely, the discoveries of numerous investigators have shown that every electric current passing near or through a substance produces a molecular change, which is rendered manifest in all metals, liquid conductors, and even in the voltaic arc, by the development of sounds, especially if the substances are under the influence of two currents at right angles to each other. In iron it is conspicuously shown also by electro-torsion, a phenomenon I have found and recently made known in a paper read before the Royal Society.

Numerous facts also support the conclusion that the molecular changes referred to last as long as the current. De la Rive has shown that a rod of iron, either transmitting or encircled by an electric current, emits, as long as the current lasts, a different sound when struck, and we know it also exhibits magnetism. The peculiar optical properties of glass and other bodies, with regard to polarized light, discovered by Faraday, also continue as long as the current. A rod of iron also remains twisted as long as it transmits and is encircled by electric currents; and in steel and iron the molecular change (like magnetism) partly remains after the currents cease, and enables the bar to remain twisted.

That the peculiar molecular structure produced in bodies generally by the action of electric currents also possesses a definite direction with regard to that of the current, is shown by the rigidly definite direction of action of magnetized glass and many other transparent bodies upon polarized light; also by the difference of conductivity for heat and for electricity in a plate of iron parallel or transverse to electric currents; by the stratified character of electric discharges in rarefied gases, and the action of electric currents upon it; and especially by the phenomenon of electro-torsion. In the latter example an upward current produces a reverse direction of twist to a downward one, and a right-handed current develops an opposite torsion to a left-handed one; and the two latter are each internally different from the former. As each of these four torsions is an outward manifestation of the collective result of internal molecular disturbance, and possesses different properties, these four cases prove the existence of four distinct molecular movements and four corresponding directions of structure; and the phenomena altogether are of the most rigidly definite character.

As an electric current imparts a definite direction of molecular structure to bodies, and as the attractions and repulsions of electric wires are between the wires themselves, and not between the currents, repulsion instead of attraction must be due to difference of direction of structure produced by difference of direction of the currents.

Although the Ampèrean theory has rendered immense service to magnetic science, and agrees admirably with all the phenomena of electro-magnetic attraction, repulsion, and motion, it is in some respects defective; it assumes that magnetism is due to innumerable little electric currents continually circulating in one uniform direction round the molecules of the iron; but there is no known instance of electric currents being maintained without the consumption of power, and in magnets there is no source of power; electric currents also generate heat, but a magnet is not a heated body.

If, however, we substitute the view that the phenomena of attraction and repulsion of magnets are due, not to continuously circulating electric currents, but (as in electric wires) to definite directions of molecular structure, such as is shown by the phenomena of electro-torsion to really exist in them, the theory becomes more perfect. It would also agree with the fact that iron and steel have the power of retaining both magnetism and the electro-torsional state after the currents or other causes producing them have ceased.

According to this view, a magnet, like a spring, is not a source of power, but only an arrangement for storing it up, the power being retained by some internal disposition of its particles acting like a "ratchet," and termed "coercive power." The fact that a magnet becomes warm when its variations of magnetism are great and rapidly repeated, does not contradict this view, because we know it has then, like any other conductor of electricity, electric currents in-

duced in it, and these develop heat by conduction-resistance.

According also to this view, any method which will produce the requisite direction of structure in a body will impart to it the capacity of being acted upon by a magnet; and any substance, ferruginous or not, which possesses that structure has that capacity; and in accordance with this we find that a crystal of cyanite (a silicate of alumina) possesses the property, whilst freely suspended, of pointing north and south by the directive influence of terrestrial magnetism, and one of stannite (oxide of tin) points east and west under the same conditions.

THE PRESERVATION OF TIMBER.

From "The English Mechanic and World of Science."

Some time back (p. 1, Vol. XV.) we gave a brief account of the various processes which had been tried, with more or less success, for the preservation of wood. Many of these required that the timber should be thoroughly dry before being treated with the preservation solutions, but the numerous experiments made in the endeavor to accomplish this, proved conclusively that even when successful, the expense was so great that wood so preserved was likely to be employed only under exceptional circumstances. Soaking timber in antiseptic solutions has been tried and found fairly successful, but in some cases even this simple process has been found too costly for the advantages it confers, Thus the creasoting of railway-sleepers has been given up by many of the companies, because the extra endurance of the wood is not equivalent to the cost of the preservative process; and in other processes where the result, so far as lengthening the life of the timber is concerned, is as satisfactory, the value of the chemicals and the time required for their operation prohibit the widely-extended use of timber so prepared. The best results hitherto have been obtained by the use of chloride of zinc, creasote, corrosive sublimate, or sulphate of copper, either of which is found to impart an antiseptic property which endures for a longer or shorter time. These substances are, however, used singly, the wood being either simply soaked in them with or without the application of heat, or impregnated with them by means of pressure. Of late years attention has been turned to the production of an insoluble chemical salt in the pores of the wood by first saturating the log with a solution of one salt and then repeating the process with another, the object being to fill the pores with an insoluble substance by means of the well-known chemical action of interchange. Thus, wood soaked in a solution of phosphate of soda, and afterwards in one of chloride of barium, was found to resist the action of moisture so well, that after twelve months' exposure to conditions calculated to insure rapid decay, it was found perfectly unchanged; but the cost of the chemicals prevents the adoption of this process to any extent. The application of soda, soap, and sulphate of copper, has been found to act as an excellent preservative; wood and timber soaked in green vitriol and afterwards in a solution of soluble glass, has also been found fairly preserved. Still, so far as we know, nothing has been discovered giving superior results to those obtained by the use of phosphate of soda and chloride of barium.

Two patents have, however, recently been taken out for methods of preserving wood, which, if they do not accomplish all that is desired, may possibly lead to the invention of processes that will. Thus Mr. W. Leech takes 1 lb. of arsenious acid and dissolves it in 4 gals. of water; to this he adds 1 lb. of carbonate of soda, stirring the mixture till it is thoroughly dissolved. In a separate vessel he makes a solution of 16 lbs. of sulphate of copper in 16 gals. of water, mixes the two solutions together, and places them in a wood or a lead-lined vat. The timber is placed in this bath, and the solution heated by means of steam to the boiling point. A few hours' soaking is said to be sufficient, but when heat is not applied the wood must remain for at least two or three days. These solutions are applicable to wood that is already in permanent position, as telegraph poles, fences, and gates.

In these and similar cases one solution should be painted on and allowed to dry before the other is applied. When possible they should be laid on hot.

Mr. J. C. Mewburn patents a much simpler and less costly process, which, so far as oak is concerned, consists simply in boiling the wood in a solution of gallo-tannic acid, the proportions of the respective ingredients being apparently immaterial. The result is the formation of an insoluble substance in the pores of the wood. One solution only is necessary for oak, on account of the tannin naturally present in that wood, the endurance of which in moist situations is proverbial. A consideration of this fact led a M. Hatzfeld, of Nancy, to try the effect of impregnating timber with tannin, and afterwards with acetate of iron, a process which is both cheap and useful, and which is at present being tested by a telegraph company in that part of France. For many purposes sulphate of copper is an excellent preservative, but this salt is said to be readily dissolved out where the wood is exposed to rain. The direction, however, in which experimenters should look for the discovery of the simplest and best process, is that indicated by the patented inventions above described. The chemicals must be cheap, and the desired effect must be produced in the simplest way—*i.e.*, soaking, for even when the process takes a month, simple soaking will probably, in most cases, be cheaper than boiling for 24 hours.

THE EFFECTS OF UNEQUAL HEAT ON THE COMPASSES OF IRON VESSELS.*

From "The Nautical Magazine."

The paper on this subject, published in the "Nautical Magazine" for September last, has, we are glad to say, evoked still further discussion, and some of the best authorities on this matter have stated their objections to the statements and speculations made by our contributor, in a manner at once fair and courteous; but, as a serious implication is made against us of unsettling opinions by attacking well-established facts, upon which sailors may rely in the navigation of their vessels, we must now assert that, primarily, the inquiry was put forward in these pages, in order that what seemed a doubtful point might have careful thought turned upon it by men of practical scientific experience; and, if there were any truth in the supposition put forward, that it might receive practical investigation and accurate demonstration. We have been gratified to publish letters on the subject, written to the "Shipping Gazette" by Captain Evans and Mr. W. Rundell, and in every way desire complete ventilation of the views broached by our contributor; throughout, our sole object and desire having been to benefit the navigation. But we continue to think that our contributor's views are not yet found to be worthless or harmful, and we consider that if there is any truth in the supposition put forward in these pages, that the interests of the seaman will be well served if it can be clearly demonstrated; and if, on the other hand, the hypothesis has no foundation of actual fact, the sailor will again be benefited by the laying of the spectre raised by us, while Captain Evans and Mr. Rundell will be confirmed and strengthened in their well-earned authority on matters of compass deviation.

The following is Mr. Rundell's last letter to the "Shipping Gazette," and we cordially reciprocate the spirit in which he speaks of us in the last paragraph of his letter:—

"*To the Editor of the Shipping and Mercantile Gazette.*

"Sir,—In my letter of the 3d Oct., under the above heading, I pointed out that the cases quoted in the 'Nautical Magazine' as examples of deviation of the compass, arising from unequal heat in iron ships, are vague and incomplete; also that these cases, admitting their reality, and that they are correctly reported, may possibly be quite explicable by ordinary mechanical causes. It will be remembered that the examples are—(1.) A difference in the deviation as observed in the morning and in the evening in a steamer while going up the Red Sea, supposed to be due to the heat, from the sun acting on one side of the vessel in the morning, and on the opposite side in the evening. (2.) A difference of 10 deg. of deviation, in one hour, in a steamer bound from Liverpool to New York, when between Georges and Nantucket, after passing through alternate bands of warm and

* See "Van Nostrand's Magazine," Vol. IX., p. 433.

cold water. (3.) A deviation of 10 deg. in a steamer while in port, the sun at the time shining on side of the vessel. These are the facts, and they have now to be viewed in the light afforded by the following quotations, which the writer of the article makes from 'Bakewell's Electricity.' page 229:—'All that is necessary for the development of thermo-electricity is, to heat any metallic body irregularly at its extremities . . . . The quantity of electricity excited is, to a certain point, proportionate to the different degrees of temperature communicated to different parts of the same metallic bar, and does not depend on the absolute heat. Thus, the application of ice will produce an electric current, as well as the application of heat; and by applying ice to one corner, and (heat) the flame of a spirit-lamp to the other, at the same time, the effect is greatly increased.' The writer in the 'Nautical Magazine' does not at once apply these obscure sentences to explain the three examples, but asks, 'Is it not possible that we have in this a clue to the secret for which we are searching, and is it not possible that the fact of the City of Washington being out of her course was owing to the action of unequal heat on her hull, and the consequent effect on her compasses?' This would have been a reasonable sequence if he had already shown how the quotation explained the three examples; but, without first giving the application and the necessary explanation, he merely makes an appeal to our imagination. This faculty is, no doubt, useful in scientific matters, but we may fairly quote here, in reference to the imagination, the very proper remarks on the compass which occur in another part of the paper in question:—'As a useful and capable servant it may be relied on; but, if once confided in without due intelligence, and without a knowledge of the effects of outside influences on it, the good servant becomes a bad master.'

"Let us, however, without stopping to pry into the secret to which a clue is wanted, quietly examine the extract from Bakewell, and try to apply to iron vessels the remark about the heating of 'any metallic body' irregularly at its extremities. Let us try, also, to form some idea of applying cold 'to one corner,' and 'heat to the other' corner, of an iron ship, when, we are told, 'the effect is greatly increased.' What parts of the iron ship represent the extremities, and which the corners here spoken of? The bow and stern may, perhaps, fairly represent the 'extremities,' but the 'corners' will afford scope for a good deal of imagination, even when we explain that in thermo-electric experiments bars of different metals are frequently united together at the extremities in a way which makes an angle or corner; and further explains that the thermo-electric effect, when it is produced, depends very much on the difference of temperature at the opposite extremities of the bar, or, if more than one pair of bars of two metals are used, on the difference of temperature of the alternate corners where the two metals are united.

"We will not be too exacting, or put the writer of the article into a 'corner' by asking where the two metals properly arranged for producing this electrical effect are to be found in an iron ship; but we will assume that they may easily be found, and in positions in which thermo-electricity may be produced: 1. When the sun is shining on either side of the vessel. 2. By an iron ship entering or leaving spaces of warm or cold water, when, of course, the 'extremities,' for a few moments, would be 'unequally,' and, perhaps, as Bakewell also seems to require it, 'irregularly' heated; 3. By a uniform, or irregular, difference of temperature between the bottom and top sides of a ship, whether sailing in warm or cold water. Let us grant all these assumptions as necessary to the explanation of the three examples; there are yet some others which must be made, and which must not be forgotten.

"Thermo-electricity, then, to use popular language, is unlike ordinary electricity, it cannot pass through spaces of air; neither can it, like galvanic-electricity, pass through somewhat tarnished metallic surfaces; it requires what is termed good, clean, metallic contact, for rust or dirt would stop it altogether, and would break the circuit which is necessary to the production of any effect on the ordinary compass needle. Any one who has seen rivets and but straps taken from an iron ship will know that such clean metallic contact does not occur throughout an iron vessel; but we make light of all such difficulties, and many others which intervene, for the purpose of testing, in imagination, the effect of a thermo-electric current, strong enough to act at a distance of some feet, on the com-

pass of the steamer in the Red Sea, example No. 1.

"The effect of the thermo-electric current on the magnetic needle is this. It tends to place the needle at right angles to the direction of the current, and moves the north end of the needle to the right hand when the current is passing in one direction, and to the left hand when the current passes in the opposite direction, if the needle be on the same side of the current. Now, we may suppose that the thermo-electric current in the steamer in the Red Sea, either passed round the sides of the vessel horizontally from right to left or from left to right; or that it passed across the vessel through the beams or iron deck, either from port to starboard or from starboard to port. What then would be the effect on the compass needle under these four conditions? Simply none at all! Under one set of conditions there would be no horizontal motion of the needle, and in the other the needle is already at about right angles to the direction of the current.

"I trust, however, enough has been said to show that very little foundation exists for the supposition that unequal heat in an iron vessel has an appreciable effect on the mariner's compass. But if it had, we need not seek for it alone in the comparatively trifling changes of temperature due to warm or cold currents of water, or the presence or absence of sunshine; or to thermo-electric effects, which require for their demonstration the use of a delicate galvanometer, an instrument which does for the electrician what a powerful microscope does for ordinary vision. Did the writer of the article forget the engine and boiler space, the heat of the stokehole, the tons of coal which are burning day and night in an Atlantic steamer to keep up steam? Here we have hundreds of degrees of difference of temperature instead of the few degrees which appear to have so exercised his mind. We have here a much wider field for inquiry, and possibly a more productive one, for thermo-electric currents which fail to affect the compass, and are next to impossible in the shell of an iron ship, may, under some circumstances, materially assist to destroy parts of the boilers and machinery.

"This letter, however, is not intended to discuss such questions, but to point out the weakness of the hypothesis which ascribes compass errors to unequal heat, and more particularly to point out the bad tendency of an article which must induce in seamen a state of unreasonable distrust in their compasses, and what is worse, a disinclination to try and master a branch of their profession, which seems surrounded with so many difficulties. It tends also to paralyze action in cases of emergency, by leading the navigator to suppose that in his compass he has to deal with occult and mysterious influences, which he cannot hope to understand. As Captain Evans has observed, its tendency is to take us back twenty years, to ignore altogether the labors of those who have devoted their energies to the elucidation of what was once a difficult subject, but which has now been rendered easy, and is full of interest to all who will devote only a moderate share of attention to its study. The true friend of the seaman will direct his attention to the well-ascertained facts of the science, and amongst these, when properly understood, will be found nothing to support the idea that unequal heat, magnetic storms, electrical discharges, in the atmosphere, fogs and the like, affect to any sensible degree the navigation of an iron vessel. Such articles as the one in question tend, too, as Captain Evans also very justly remarks, to place the navigation of an iron ship beyond the scope of known physical laws, and to place the navigator of the iron ship outside the responsibilities of moral law.

"This may occasionally be a convenience to the shipmaster when in trouble, and placed before a Court of Inquiry incompetent to deal with such subjects, but it takes from him at other times all the merit of skilful and successful navigation, by reducing his success to a mere matter of chance, to the result of a balance of 'unknown,' 'unsuspected,' 'frequent,' 'temporary,' and 'ever-varying,' but happily, generally, self-compensating errors.

"Those parts of the article in question which refer to deviation from heeling, and others which underrate the importance of thoroughly testing the competence of the professional compass adjuster, also call for remonstrance; but there is no space for it at the end of this long letter. I must, however, beg permission to add a few lines, to say that I hope the object of my remarks will not be misunderstood by the editor of the 'Nautical Magazine.' As a constant

reader and admirer of that very useful periodical, my desire is to aid in making it a discreet, as well as a warm friend of the seaman. We are in many respects in the 'same boat' as the 'Shipping and Mercantile Gazette,' and I should be very sorry to have it supposed that my strong objection to the tendency of a particular article, or that your insertion of my adverse remarks, are to be taken as a sign that the general merits of the 'Nautical Magazine' are undervalued by me."

DOMES OF STONE AND BRICK.

From "The Building News."

The attention of our readers was recently called by us to the construction of iron domes for covering very large areas without the necessity of ties or buttresses, and some of the advantages, as well as disadvantages, attending the use of this material were pointed out. We now propose to take into consideration the construction of domes with more permanent and enduring materials, such as stone, bricks, or terra-cotta, and concrete or artificial stone. For such buildings as are intended to last for ages without requiring any heavy expense for repairs, the use of iron as a material for construction is scarcely admissible, unless some means can be devised of protecting it from the corrosive action of moist air. Iron has also the defect of being very sensitive to variations of temperature, expanding with irresistible force as that increases, and contracting again as it diminishes, so that a very large roof of iron may be said to be in constant motion from the changes of temperature to which it is exposed during the whole twenty-four hours of each day. Moreover, when a hot sun is shining on a dome of iron it will be heated much more on one side than on the other, which will tend to produce a distortion of its figure, and an unequal strain upon various parts; and as this goes on constantly for many years, the strength of the substructure must be gradually but surely diminished. Hence we see that, although such structures are admirably adapted for temporary purposes, and those in which rapidity of erection is an essential point, yet for buildings intended to last for centuries the only material to be relied upon is either stone or brick.

Domical vaulting has been but little used in Great Britain, and no English architect since the time of Wren, appears to have attempted to erect a large dome of stone or brick. We must, therefore, look to other countries for the finest examples of this mode of construction, and these are very numerous in Italy, Turkey, and India. Very few domes appear to have been built with voussoirs of masonry, either brick, terra-cotta, or rubble stone being the material of construction. The external dome of the Pantheon at Paris is of masonry, and of very light construction, but the weight of the lantern is chiefly supported by an inner brick dome of conical form.

When we examine the most celebrated domes that have been built in various countries, either in ancient or modern times, we find two distinctive features in their design: first, where the dome is used simply as a covering, as that over the Church of Santa Sophia at Constantinople, and has no load to carry; secondly, where the dome is employed as the chief external feature of the building, and is loaded with a heavy lantern of masonry, as is the case with those of S. Peter's at Rome, Santa Maria at Florence, and S. Paul's in London. There are also two distinct modes of construction employed in these domes; one in which the main portion consists of a number of curved ribs rising from the drum or supporting wall and gradually tapering towards the summit, with horizontal rings between them, so that the whole surface is divided into a number of panels the filling-in of which is much lighter and thinner than the main ribs themselves. The other mode is to build the whole dome with a smooth surface inside and out, and of uniform thickness in each horizontal course, so as to be perfectly homogeneous throughout and of equal strength in every part.

The former of these systems is the one that has prevailed in most of the great domes of ancient or modern times, although the want of homogeneity which it entails has generally led to serious settlements from the unequal pressure which is thrown upon different parts of the substructure. The dome of the Pantheon at Rome (142 ft. diameter) is built in this manner, with

ribs and rings dividing the internal surface into deeply recessed panels; the enormous thickness, however, which has been given to every part of this vault, and its supporting walls, render it perfectly safe from all risk of settlements, and, indeed, the thickness at the thinnest part of the panels is much more than sufficient to secure the dome, even if all the extra thickness of the ribs were taken away. A similar system was employed in other old Roman domes, as that of the temple of Minerva Medica (81 ft. diameter), where the ribs were standing by themselves long after the filling-in to the panels had been destroyed.

Coming to more recent times, we find the dome of Florence (138 ft. diameter) built on the same system; the plan is an octagon, and there is a vertical rib at each of the eight angles with an intermediate rib in the middle of each side. There are no horizontal rings, but the filling-in between is of such great thickness as to obviate the necessity for them. The only external tie which has been used to prevent horizontal thrust upon the drum is round the bottom of the dome. There would, however, be but little horizontal thrust in a dome having its section, which is that of a pointed or Gothic arch, and the great thickness of its double casing renders its stability certain so long as the substructure does not yield at any point. The cupola of S. Peter's at Rome (139 ft. diameter) is built in a similar manner to that of Florence, but on a circular drum instead of an octagonal one. Several settlements occurred in this dome, but these arose from defects in the foundations and supporting piers, and not in any want of stability in the dome itself. All these domes are constructed either of brick or rubble masonry, and not of hewn stone worked into the form of voussoirs.

In the external dome of the Pantheon at Paris, which is 78 ft. external diameter, the construction is of regularly-coursed masonry, the rib and panel system being adopted. This dome is, probably, the lightest in proportion to its size that has ever been built, the thickness of the ribs being 26 in. at base and 13 in. at the summit, giving a mean thickness equal to one forty-fifth of the diameter, while the panels are only one-half that thickness. There is a stone lantern above, but the external dome has very little of its weight thrown upon it, which is chiefly borne by an inner cone of brick, as in the dome of our own S. Paul's.

The second mode of construction employed in forming a domical vault is where the whole dome is made of uniform thickness, and not divided into ribs and panels; and this appears to be the most proper, as well as strongest, mode of constructing a large dome, which may be formed either of hewn stone cut in the wedge form, or else of rings of ordinary bricks, or hollow voussoirs of terra-cotta. We have a fine example of this kind of construction in the dome of Santa Sophia at Constantinople, which is nearly a hemisphere of 110 ft. diameter, and is elevated on a circular drum. Internally, the springing of the dome is about 5 deg. above the horizontal line through the centre of the generating circle. Externally, the dome begins at a point which would make an angle of 30 deg. with the centre, and is nearly uniform in thickness above that point, being 2 ft. thick at the crown; below 30 deg. the thickness is about 5 ft. There is little doubt that such a dome, which is without any lantern or load at the summit, would be perfectly stable even if there was much less thickening out at the base, provided the supporting piers and walls did not settle unequally at any part. The great dome of the Gol Gomuz, at Beejapore (124 ft. diameter), is of uniform thickness throughout, but that thickness is so enormously great—about 10 ft.—that it can hardly be taken as a fair example of a well-constructed dome.

We will now briefly consider domes in their two distinctive features—namely, first, those which have no heavy lantern to support, and, secondly, those in which the lantern forms an important part of the design. Where the dome has only its own weight to carry, the problem of stability is a very simple one; we must first make sure that we have a solid foundation, and that our piers or walls are well constructed with regular courses of masonry, and not filled in with rubble work, by which all the weight of the superstructure will be thrown on the outer casing of ashlar, which has been the principal cause of the failure of many large cupolas. If we build our dome in ribs and panels we must also take great care that the pressure of the ribs is distributed as uniformly as possible over the whole of the points of supports so as not to produce unequal settlement. The thickness of the dome

at the base should be about $\frac{1}{45}$ of the diameter if hewn stone is used in the construction, as in forming an arch. This thickness should be diminished upwards to about $\frac{1}{2}$ the thickness at the base; and if in ribs and panels, the latter may be made half the thickness of the ribs. Such a dome, constructed of masonry carefully fitted, will require no outside belt to prevent bursting or thrusting, provided the walls are of a thickness considerably greater than that of the dome, such thickness depending upon the height they are carried up from the ground.

It was proposed by Rondelet, at the end of the last century, to put a domical roof of hemispherical form over the Halle au Blé (Cornmarket), at Paris, to be built of hewn stone, with a diameter of 130 ft., the thickness at the springing to be 28 in., diminishing gradually to 14 in. at the summit. An eye was to be formed in the centre of the dome 25 ft. in diameter, and a light iron lantern weighing 4 or 5 tons, erected over it. The average thickness would be $\frac{1}{70}$ of the diameter. In this case the weight of the lantern would have been considerably less than that of the portion of the dome cut out to form the eye, and as that is the part which presses most heavily on the lower portion of the dome, by cutting it out we reduce very much the risk of outward thrust, and no external belts will be necessary. Unfortunately, Rondelet's design was not carried out, but one of timber erected instead.

Most of the remarkable domes have, however, to carry the weight of a stone lantern, vastly heavier than the masonry omitted to form the central eye. Such a superstructure, placed where it produces its utmost possible effect, would inevitably burst out such thin domes as we have just noticed, unless they were very strongly tied in with belts of iron surrounding the lower parts of the vault. Hence we see the reason why those of St. Peter's, at Rome, and Santa Maria, at Florence, have such great thickness given to them as about $\frac{1}{5}$ of their diameter. It is almost impossible, also, to build large domes, having such a thickness, of solid masonry, and brick has, therefore, been invariably used in their construction. Brick has, however, the defect of being of variable strength, and requiring a much larger quantity of mortar or cement than masonry does; consequently, the risk of settlements is vastly increased, and the necessity arises for increasing unduly the thickness of the dome, and of also removing all risk of its bursting asunder by putting iron belts around it. In spherical domes the weakest part is about 20 deg. above the springing, and in such a dome as that at Florence it is about 13 deg. above the springing line; so that the greatest effect of a belt is obtained by placing it round the dome at that point where the tendency to bursting is greatest. If such domes as those of Rome and Florence were to be built of masonry they would be quite stable if only half their present thickness, and would carry their heavy lanterns without thrusting out the drum or bursting at the haunches. The dome of St. Paul's, in London, has a lantern of enormous weight to support; but in this case the real dome is concealed from view both externally and internally, the lantern being carried on a brick cone, 18 in. thick, which inclines to the horizontal at an angle of 66 deg. The inner dome which is seen from below is also of brick, 18 in. thick, built in form of a hemisphere with a large eye cut out of the centre, and having no load whatever to support. The external dome, which forms the grand feature of the building, is a framework of timber supported upon the internal cone before mentioned. The conical form of vaulting is, no doubt, far stronger than any other, and next to it in strength and stability is the paraboloid, whose vertical section is a parabola, having its axis vertical; then comes the dome having a pointed Gothic arch for its section, the strength of which depends on the pitch of the arch. All these forms of dome will bear the load of a lantern better than the hemispherical one, and will have less tendency to burst. Segmental domes, as they are called, whose section is a segment of a circle, in which the springing is not more than 52 deg. from the vertex, have no tendency to burst, but rather to fall inwards, which must be resisted by a belt at the springing, or by having the supporting walls of a sufficient strength to resist the outward thrust thereby produced.

In building a brick dome of large size to carry a heavy lantern, iron belts should be introduced in all the lower portion, beginning at a little distance above the weakest part or point of rupture before mentioned; this can best be done by introducing hoop-iron into the mass of the brickwork, or if hollow bricks or terra-cotta voussoirs were

used, the hooping might be threaded through the bricks and securely fastened at the ends. By this means a greater degree of homogeneity is imparted to the structure than by placing iron belts round the outside. Domes built of solid masonry, in which each stone is a "through," can be prevented from bursting by having dovetailed iron dowels let in at each abutting joint, and run with lead, so as to form one continuous chain all round, which no pressure from above short of crushing the material could possibly rend asunder.

Many persons make the mistake of regarding a dome as an arch, but in reality the two have but little in common. A large stone arch requires a strong scaffolding or centring to support the stones in the upper part until the key-stone is fixed; whereas, as soon as any one horizontal course of a dome is completed, it requires no further support, and we only need to keep the stones or bricks of each course in their places until the whole ring is filled in; so that no centring is required for dome building, a travelling pole having a cap at the outer end being sufficient to keep the courses in place until the cement is set on the ring finished; and even this can be dispensed with if we notch or dowel one course on the top of that below it. The thrust also of a dome is much less than that arising from an arch of equal diameter, and can be counteracted with greater readiness in the way we have seen. Although, however, the thrust of a dome is much less than that of an arch, yet analysis shows that whereas that of an arch increases as the square, or second power of the span, the thrust of a dome increases as the cube, or third power, of the diameter; this fact must be borne in mind in designing the supports of very large domes, which must be made thicker in like proportion.

There is another kind of material that we have not yet noticed, but which might be advantageously used for the construction of domes, namely, concrete, or artificial stone. This material has been extensively employed in the construction of walls, arches, and vaults, and, when properly treated, it appears to possess great homogeneity and power of resisting strains. There are two ways in which such material can be employed in dome building—one in which it is first cast into blocks of a suitable size and shape, and then built into its place in the way that stone would be used; the other mode is, form a kind of box, in the exact position in which the dome is to stand, and fill-in with the concrete in a loose state, the box being shifted to another part as the material sets and hardens. With this material it is advisable to permeate the mass with plenty of hoop iron, so as to give it tensile, as well as compressive strength, and prevent unequal settlements occurring and producing fractures.

With the great experience which we possess in modern times of the strongest as well as weakest forms of domical construction, and the knowledge that has been acquired of the strength of materials, we ought to be able to erect domes of stone, brick, or other durable material, which shall completely eclipse those of ancient times, both in magnitude and elegance of design.

Those who wish to make themselves acquainted with the mathematical theory of dome vaulting will find the subject fully and ably discussed in a paper by Mr. E. W. Tarn, read before the Royal Society in 1866, published in the "Proceedings" of that year, and afterwards in the "Civil Engineers and Architects' Journal" for March, 1868; also in an elaborate and exhaustive paper by Mr. E. B. Denison, read before the Institute of Architects, in February, 1871. By carefully comparing the theories with practical knowledge of construction, the architect is enabled to judge how he can best use the materials and other means at his disposal so as to produce an edifice combining stability of structure with elegance of design.

ASPHALT AND WOOD PAVEMENTS.

From "The Architect."

Mr. William Haywood, the City Engineer, has presented another report on asphalt and wood paving, with the object of showing the relative advantages of both. Wood pavement was laid down in the Old Bailey in 1839, and then in other streets, but none of them lasted more than seven years. The streets were then not cleansed

as well as now, nor was the mode of preserving the surface well understood. Experience in pavements was almost entirely confined to granite of a superior quality to that which now comes to London, and of stones more than double the size of those now generally used; and as the duration of some of the wood pavements was so small, and their cost much larger than granite, a prejudice appears to have arisen against wood, and the pavements, as they wore out, were for the most part replaced with granite.

Wood was, however, retained in Mincing Lane, Gracechurch Street, Cornhill, Lombard Street, Bartholomew Lane, Lothbury, and in part of the Old Bailey, until within the last three years, when, with the exception of that in Bartholomew Lane, it was replaced with asphalt.

At the end of 1873 five descriptions of wood paving were in existence in the City, viz., Carey's Improved Wood, Ligno-Mineral, Mowlem's, and Stone's. Their total length was 1,059 yards, and the superficial area 12,238 yards.

The first asphalt pavement was laid in Threadneedle street in May, 1869, and was formed of the compressed asphalt of the Val de Travers Company. Cheapside and the Poultry were laid with similar asphalt in the autumn of 1870, and many thoroughfares have since then been paved with it and asphalts of other kinds.

At the end of the year there were six descriptions of asphalt, viz., Val de Travers (compressed); Val de Travers (mastic); Limmer (mastic); Barnett (mastic); Société Française (compressed), and the Montrotier (compressed). The total length was 7,484 yards, and the area 60,802 yards.

Mr. Haywood says that no two pavements, whether of asphalt or wood, are exactly similar in their qualities, nor will they be of the same durability or cost. It may be necessary specially to refer to some, although, for the most part, the remarks in the report will be applicable to asphalt and wood generally. Nevertheless, as it is needful to make direct comparison upon some points, the Compressed Asphalt Pavement of the Val de Travers Company and the Improved Wood Pavement have been selected as being the best examples of their several kinds, and of which there are the largest quantities now laid in the City, and elsewhere in the metropolis. The following is a brief description of them:—

The Compressed Asphalt Pavement of the Val de Travers Company is formed of a natural material, procured from a mine in Switzerland; it is laid upon a bed of cement concrete, in a state of heated powder, and so as to be, when compressed, from 2 to 2½ in. in thickness, according to the traffic of the street.

The Improved Wood Pavement is formed of fir blocks, 3½ in. wide, 10 in. long, and 6 in. deep, laid upon a foundation of two thicknesses of fir planks, well pitched and nailed together; the blocks are placed together at their short ends, but on their longer sides are joints, running from side to side of the street, ¾ in. wide, the lines of joint being kept by fillets nailed to the planks; the joints are filled up with clean, small pebbles rammed in, and then run with a composition, formed of pitch, tar, or other bituminous substances.

With regard to asphalt, Mr. Haywood says, that although there is much larger experience in its use than there was in 1871, when he reported upon the comparative merits of asphalt and granite pavements, he sees no reason upon most points materially to alter the views and opinions then expressed, and much then said has been repeated in the present Report.

The qualities of the pavement considered in the Report are their (1) convenience, (2) cleansing, (3) construction and repair, (4) safety, (5) durability and cost.

Convenience.—The principal, if not the sole, object of employing either asphalt or wood for pavements is to diminish the noise of the traffic. Asphalt is less noisy than granite; for, being smooth and without joints, wheels run almost as easily over it as on a tramway, and the noise is caused almost entirely from the clatter of the horses' feet. Wood is less noisy than asphalt, the horses' feet making no clatter upon it; in fact, wood makes the most quiet of all known pavements. Asphalt cannot be suffered to get materially out of repair, for if it does it is speedily knocked to pieces; therefore, the quietness and the comfort it affords will be at all times nearly the same. Wood pavements, being composed of blocks of different sizes and jointed in different manners, are in the course of time worn into inequalities, and carriages are then more jolted and there is more noise than when the pavements are new; but this is principally experienced by those inside the carriages.

The extent to which this irregularity of surface takes place depends much upon the care taken in its maintenance, but also upon the nature of the pavements; those formed of large blocks with wide joints wear more unevenly than those of small blocks with close joints. The owners contend that their Improved Wood Pavement, having no short joints and the blocks reposing upon a slightly elastic foundation, will not wear unevenly, and probably it will wear more evenly and last longer than any other wood pavement yet laid, but it certainly will wear somewhat round in the direction of the traffic. Pedestrians, where the carriage traffic admits of it, walk largely upon asphalt, but they do not walk so much upon the wood.

Asphalt being impervious, water runs off it quickly or is soon evaporated. Dirt lingers in the joints of wood pavements, and is worked out by the traffic, making the surface dirty for some time after rain. The relative advantages of the two pavements in this respect depend, however, largely upon the care taken in cleansing. Wood absorbs moisture, and is very frequently damp when asphalt is dry; but if it be reasonably clean, the dampness does not affect the safety or comfort of the traffic. When dry weather ensues after rain, dust clings to the wood, and there is no dust for some time.

It has been said that wood pavements at times smell offensively, and may be unhealthy; but although some City streets have been paved with wood for thirty years, no complaints have been made to the Commission, and the inhabitants at all times have not only expressed great anxiety lest the wood should be replaced by other material, but have subscribed towards the cost of its renewal. In the northern towns of Europe wood pavement is much used. In America and Canada many of the largest cities are paved almost entirely with wood, and it is not there believed to be unhealthy. In confined places, and under some conditions, wood might be considered unhealthy.

Are wood pavements likely to be the means of spreading a conflagration? It was found by experiments made by Mr. Haywood, in conjunction with Captain Shaw, that asphalt, subjected to a more severe test than it would be in an ordinary fire, would not aid in spreading a conflagration, and there is no reason to suppose that wood would be more likely to do so, laid, as it is, under conditions rendering surface ignition improbable. At Chicago the foot pavements were, in many cases, formed of planks laid on wooden joists, the whole structure being 1 or 2 ft. above the carriage-way, and subject to the action of the fire on both sides; but it is doubtful whether the fire was materially, if at all, increased by those footway pavements.

Cleansing. — Both asphalt and wood should be kept very clean for safety; but great cleanliness is more important to asphalt than it is to wood. Asphalt can be kept cleaner than any other pavement, for, being non-absorbent and without joints, the broom, the scraper, the shovel, or water, can be applied to it most effectively. Wood pavements are more difficult to clean on account of the joints and the absorbent nature of the material. Experiments made in 1867 and 1873 in washing granite and asphalt with jet and hose, showed that asphalt costs slightly less than granite; but that a higher state of cleanliness can be attained on it. It is probable that the cost of washing wood would also be more than that of asphalt. Washing is the best way of cleansing all pavements, and it is desirable that an experiment be made on wood at an early opportunity.

Construction and Repair.—Compressed asphalt, with a concrete foundation, was laid in Cheapside at the rate of 129 yards a day, and the Improved Wood Paving was laid in Ludgate Hill at the rate of 125 yards per day. Other wood and asphalt pavements can be laid as expeditiously—that is, in fine weather, for in wet weather neither the concrete foundation nor the asphalt can be laid. Wood blocks, if not requiring a concrete foundation, can be laid in most weathers, but the grouting of the joints, whether with lime or asphalt, cannot be properly done unles the weather be reasonably dry. The same remarks apply to repairs both to asphalt and wood in respect of weather.

Very small surface repairs can be made with facility in all asphalts. In compressed asphalts they can be made so neatly as not to be noticeable after a short time, but in the mastic asphalts the joints remain visible. The ease with which repairs can be made to a wood pavement depends upon its character; ordinarily they can be done with the same facility, and are executed in much the same manner as to granite.

As regards the safety of the two pavements, we noticed on January 10 the special report of Mr. Haywood on this part of the subject, so we need not now repeat what is said in the present report.

Durability and Cost.—There is not enough experience to determine the durability of asphalt. During the past three years eleven different sorts have been tried, five of which have failed; and there are others in an unsatisfactory condition, some showing unmistakable signs of decay, and the necessity for a not far distant renewal or extensive reparation. Compressed asphalts have hitherto proved themselves the most durable; those which had been the longest down were examined carefully last year, and the loss on them by wear found to be small, and they were generally in good surface condition.

More than two dozen different kinds of wood pavement have been tried in the City. The average life of wood in three streets with the largest traffic was about nine years, and in three streets with the least traffic about eleven years and a quarter. Nearly all, before they were removed, had been relaid over their entire surface, and some new wood introduced from time to time in lieu of that found too defective to relay. In New York it has been found that the average duration did not exceed five years. The general conclusions which Mr. Haywood draws are:—

(1.) *As regards convenience.*—That Asphalt is the smoothest, driest, cleanest, most pleasing to the eye, and most agreable pavement for general purposes, but Wood the most quiet.

(2.) *As regards cleansing.*—That Wood may be kept cleaner than it has hitherto been, but will be more difficult and expensive to cleanse effectually than Asphalt. That as both pavements require occasionally strewing either with sand or gravel, there is not much difference between them in that respect.

(3.) *As regards construction and repair.*—That Asphalt and Wood, taking all seasons and weathers into account, can be laid and repaired with about equal facility, but that the smallest, neatest, cleanest and most durable repairs can be made in Asphalt.

(4.) *As regards safety.*—That whether considered in reference to the distance which a horse may travel before it meets with an accident, or the nature of the accident, or the facility with which a horse can recover its footing, or the speed at which it is safe to travel, or the gradient at which the material can be laid, Wood is superior to Asphalt.

(5.) *As regards durability and cost.*—That Wood pavements, with repairs, have in London had a life varying from six to nineteen years, and that with repairs an average life of about ten years may be obtained; that the durability of the Asphalts is not known, but that under the system of maintenance adopted, they may last as long as Wood; that contrasting the tenders for laying and maintaining for a term of years the two best pavements of their kinds, Wood will be the dearest.

Although the foregoing remarks apply in most cases to Asphalt and Wood pavements generally, yet they are more strictly applicable to the compressed Asphalt of the Val de Travers Company and to the Improved Wood Pavement, and where the climate and other conditions differ widely from the metropolis, different results as to safety, cost, etc., may be expected.

ON FIRE-PROOF BUILDING.*

From "The Builder."

The ordinary construction, called fire-proof, consists of brick arches carried on iron beams, which generally rest on iron columns for intermediate support, the end arches being tied by iron bars to prevent outburst of the walls; and what generally happens when a fire takes place is, that the columns become softened or split by a dash of cold water while they are very hot, or the under side of the girder—which is generally exposed to the greatest strains—is weakened by heat or split by suddenly cooling, or the tie-rods lose their tensile force; the floors fall in, the walls fall out; and the very process adopted for the preservation of the building greatly facilitates its total destruction. Of the two, a com-

* By Mr. James H. Owen, M. A. Read at a meeting of the Architectural Association of Ireland, December 18th, 1873.

mon timber floor, well sealed underneath, would have lasted longer, thereby giving more time for salvage, and could not, at the worst, have suffered more than the pseudo-fire-proofing; but still something can and must be done to protect the ironwork, as by its means alone can the sort of structure which is required for the business be erected with the necessary stability.

In designing such a building, the architect should first ascertain the smallest area that he can be allowed to use as the unit of construction; he should subdivide by internal partition-walls as far as he will be allowed to do so; and, having thus arrived at the cubic spaces of which the intended building is to be composed, and finding that the spaces over which he has to carry his floors render it necessary to avail himself of the constructive facilities afforded by iron, he must set himself to work deliberately to contrive such a mode of using it as will protect the iron from the effects of fire. If columns are required for intermediate support, I think they might be of iron, of somewhat larger diameter than usual, and the interiors filled solidly with cement concrete, carefully packed and rammed, the idea being that the cement should form an interior column capable of sustaining the load in the event of the iron failing; or of +-shaped iron, with a coating of brick in cement; or, best of all, a simple shaft, with cap and base constructed of bricks laid in fine Portland cement, as nearly skin to skin as possible. These would be not very sightly; but that is of very slight importance when the enormous damage to be overcome is considered; but as it is not worth while to make anything uglier than it need be, I should recommend a shaft square on plan, with edges chamfered, and stopped at top and bottom. This would have the appearance of a clumsy timber post; but a series of them would not look amiss. Then, as regards the floor itself, in which I include not the surface only, but the whole mass from floor to ceiling which separates the two stories, —what we have to do is to support an area, say 15 ft. or 20 ft. square, and at the same time present to the action of fire a surface, above and beneath, which shall be absolutely uninflammable, and which shall not be subject to any alteration of dimensions or strength by the action of fire,— not be destroyed by the action of wet. I believe these objects would all be attained as nearly as possible by the construction which I have sketched, which consists of a beam of rolled iron resting on a cushion of brickwork not less than 3 in. over the finished top of the pillar. When the beam is set it should be painted and well sanded all round; then a platform or centring should be erected of the exact form of the intended under-surface of the ceiling when finished; over this tiles of any pattern that may be approved should be laid, face downwards, filling up the whole surface; the remaining space should be then filled in to the level necessary for laying the floor tiles with a concrete prepared of Portland cement, sharp silicious sand, and broken bricks and potsherds, or broken granite or sandstone, carefully excluding all calcareous stone, gravel, or sand. The upper surface should be properly levelled and floated, and a course of flooring tiles laid and grouted with cement in the ordinary way. The supports of the centring should be suffered to remain as long as possible, and it would be advisable in all cases to finish each floor complete *pari passu* with the walls, letting the cement concrete which forms the floors rest solidly for some inches in and on the outer walls.

There are, I confess, doubtful, or rather unsettled, points about this construction, viz.—1st. The proportion of the load to be supported by the iron girders, and consequently what the proportions and sectional area should be. 2d. The transverse strength of beams or slabs of cement concrete; no experiments that I have been able to find have yet been made to determine this. 3d. Whether the tiles forming the under coating would not be detached by fire or water suddenly dashed against them when hot. I would wish to say a few words on each of these points. First, as to the basis of calculation of the load to be borne, or the amount of work to be done, by the iron. It will be observed that from the nature of cement concrete it differs from a floor formed either of beams and joists or of a brick arch, inasmuch as it resembles a slab of stone; and in that it is at one and the same time, both in load and self-supporting, within moderate dimensions, we can readily conceive a square slab of concrete to be independent of support except on two sides of it. And here comes in the second doubtful point. If we had the strength of a slab of concrete stone as well known as that of a slab of granite or lime-

stone, we should know exactly that with a certain thickness we could use it with safety for a certain projection beyond the supporting wall. To take an example: no architect would venture to fix a landing of granite projecting 4 ft 6 in. from the supporting wall, and 6 in. thick, or to cover a space 9 ft. between the walls by slabs of granite 6 in. thick; in either case it would be recognized that iron beams under the joints would have nothing to do—would be superfluous. We have not that experience as regards slabs of concrete; we do not know how far they are to be trusted; and therefore I recommend the employment of iron in conjunction.

The only experiments of which I have any knowledge which have been made in this direction are those of M. Vicat, and one made at the Great Exhibition of 1851. M. Vicat made a beam of hydraulic lime and granite sand (beam fixed at one end and loaded at the other), of the following dimensions:—

Experiment No. 7.—L 0.03 c.=.09827 ft.
D 0.025 c.=.98427 in.
B 0.04=1.5748 in.
W 32.00 kil.=.62096 cwt.

Experiment No. 8.—47.00 kil.=.92515.

Applying the general formula $W = c\frac{b\,a^2}{L}$ we find the value of c to be, in No. 7, .16 cwt., and in No. 8, .235 cwt. These results are very low as compared with the value of c for other materials; as, for instance, 3 for Riga fir, 4 for red pine, 18 for cast-iron, etc. I cannot help thinking that the exceedingly small dimensions operated on were very unfavorable for an experiment of the kind on such a material.

The experiment made at the Great Exhibition of 1851 was somewhat similar. The beam was of pure Portland cement, 14 in. long, 4 in. × 4 in., and it bore 1,580 lbs. Adopting the same formula, this gives a value of 1.174 cwt. for c, or rather more than one-half the value for Riga fir. But as Portland cement loses its strength very materially by admixture with sand, we must reduce the constant very materially for this reduction; but, on the other hand, there is nothing easier or more natural than to increase the strength of the Portland beam by giving it a curved form underneath; and for the same reasons that we make a beam of iron of a parabolic form in order to collect the materials exactly in to the place where they will produce the maximum of effect, so we should give the beam of Portland cement an arch form of the same shape underneath; and it is not improbable that this expedient would make up for the loss of strength caused by adding sand and gravel to the cement—or, in other words, of using concrete in place of pure cement.

One other thing to be borne in mind is, that in all cases of using cement concrete for covering over spaces, the value of B becomes extended. In an ordinary beam we have B only a few inches, and bearing the weight of an average of 10 ft. of floor. In the Exhibition experiment the weight amounted to nearly 4½ cwt. per ft. superficial of floor; and as the exterior weight for warehouses and factories is only reckoned at 2½ cwt. per superficial foot there was evidently great excess of strength, considering the proportion of 4 in. of breadth to 10 ft.

I must not dwell longer on this subject, or you will fancy I can never get down from my hobby. I do hope, however, that those who have the opportunity will try really testing experiments on concrete in this sort of application, and publish them for the benefit of the profession. I feel rather confident that the result will be, that floors and ceilings combined can be constructed of concrete, which shall rival any other form of material as regards price, strength, and economy of space.

I think it desirable to add a few words as to precaution which may be used in lessening the tendency to catch fire in buildings which are not in their nature actually non-inflammable or intended to be so. Whenever timbers are exposed, it is very desirable to cover them with a coating of common whitewash, which acts doubly as a preservative, both by excluding air from the timber, and from its non-conducting power. This will, of course, be of no use when a fire has once been kindled and got to a head; but in case of fire seconds of delay in kindling it or communicating it are of vital importance. In many a workshop or factory, if the floors and roof timbers were kept well whitewashed the risk would be much diminished. Special precaution should be taken about the floors and fireplaces: there is frequently great carelessness in trimming joists and fixing grounds for skirting, etc. It would be very desirable always to skirt chimney-breasts in cement or plaster, and to fill in the place under the hearthstone with cement con-

crete. Ceilings, again, should be formed with much stronger laths and better nailed; and if about 2 in. of rough mortar, the coarser the better, were laid over the laths between the joists, it would be found very difficult to set fire to them—they would resist for a considerable time even a fierce fire underneath. Again all rooms should have a good height, otherwise the constant operation of gas-lights is to prepare the timber of the ceilings for combustion on the most rapid scale, if the opportunity be once given. As regards all stoves, great attention should be paid to their being so arranged as to avoid all risk arising from the heat of the stove itself, its flue-pipe, or its ash-pan; no stove should be considered safe the flue-pipe of which cannot be heated to redness with perfect safety to the building. But in all ordinary buildings the most important point to attend to is the staircase: it seould be, if circumstances will admit, closed at top or bottom, cut off from the passages leading into the rooms, and in the construction of it it is very desirable to lath the soffits with extra strong laths, and fill in from the upper side with concrete, so that all the space at the back of the riser and under the tread shall be a solid mass of non-inflammable material. Such a staircase would probably stand and bear the weight of persons ascending and descending under circumstances where an iron or stone staircase would be destroyed or useless.

A TORPEDO DETECTOR.

From the "Times," London.

Captain Harvey, R. N., the inventor of the towing Otter torpedo, lays it down as a primary rule in his tactical instructions for the use of the weapon, that an attack upon ships by torpedoes should always be made, if possible, under the cover of night. The Naval Torpedo Committee have given the subject of attack by torpedo boats at night upon ships at anchor considerable attention, and have proved by experimental practice that in the majority of instances the torpedo attack upon the ship must be successful. The Monarch, one of the ships experimented upon, was anchored at Spithead, and on one occasion was considered to have been made almost impregnable against any attack by a strong crinoline framework of booms and spars built up round, supplemented by her boats rowing guard round her within hailing distance. The ship had also the advantage of knowing that a boat torpedo attack would be made upon her, and the time when the attack might be expected. Notwithstanding these important advantages in the ship's favor the torpedo boats—steam pinnaces—burst through the Monarch's cordon of guard boats, got over the difficulty of the projecting crinoline spar defence, and struck the frigate with their dummy torpedoes. These results proved that any vessel lying at anchor at night must be fatally deficient in her defensive powers in a want of means for searching with lightning quickness and distinctness the surface of the water to a considerable distance around the ship. To supply this want effectually, Mr. H. Wilde, of Manchester, some time since submitted to the Admiralty a proposition for the use of one of his electro-magnetic induction machines, fitted with a proper apparatus for projecting the beam of light produced upon distant objects. One of these machines has been fixed on board the Comet, twin screw gun vessel at Portsmouth (one of the short and light draught boats carrying one 18-ton gun on a raising and lowering platform, on the Armstrong-Rendell plan), and was tested during the nights of Thursday and Friday last, under the supervision of Captain Boys, and members of the Naval and War Office Torpedo Committees, with the most complete success.

On Thursday week the Comet left Portsmouth harbor for the eastern entrances to Spithead, from the Channel, at about 8 P. M.; but half an hour before leaving, a first experiment was made with the machine and its projector lens in throwing the beam of light round the upper part of Portsmouth harbor. The results were startling. The gunnery ship Excellent, with her tenders and the boats alongside and at the boom-ends, the long lengths of the sea wall enclosing the dockyard extension works, the mud-banks—it being nearly low water—the Asia and the vessels about her, and further away into Fareham creek, her Majesty's yacht Victoria and Albert, the

Glatton monitor, and the few men-of-war boats moving about between the ships at the time, all stood out with wonderful distinctness as the electric light touched them. But, beyond all the others, the Glatton, in her French grey paint, given her as an invisible dress at certain distances by daylight, shone out in weird splendor. When the Comet subsequently left the harbor and had taken on board the members of the Torpedo Committees off Southsea, she steamed to a position off Brading and the east end of the Isle of Wight and anchored, attacks being then made upon her by two steam pinnace torpedo boats, from directions, of course, unknown on board the Comet. When the boats had been away a certain time the electric light was brought into play, its beam sweeping the surface of the water and in each instance discovering the torpedo boats before they could lessen a mile's distance between them and the Comet. Discovered at such a distance, their attack, of course, was considered to have utterly failed.

On Friday the Comet was anchored in Stoke's Bay, near the west end of the measured mile, and buoyed off for the speed trials of her Majesty's ships. Captain Boys and the members of the Torpedo Committees made a number of experiments with the light, upon which official reports will be made. On Friday, as on Thursday, no boat could approach the light within a mile without being at once discovered.

Mr. Wilde's apparatus consists of two parts—an electro-magnetic induction machine for producing the electricity, and an arrangement for regulating the light produced by the current and projecting it upon distant objects.

The electro-magnetic induction machine is founded upon a somewhat paradoxical principle—that magnets and electric currents indefinitely weak can produce magnets and currents of indefinite strength. The machine consists of a circular or cylindrical framing of cast iron, round the interior of which are arranged a number of electro-magnets at equal angular distances from each other. A cast-iron disc is mounted on a driving shaft running bearings fitted to each side of the framing, and carries a number of armatures revolving before the electro-magnets. A slight charge of magnetism is imparted to the electro-magnets before the machine is used for the first time, by transmitting a momentary current through the wires surrounding the iron cores, or by touching their extremities with the poles of a permanent magnet. This initial charge is always retained by the electro-magnets, and is the basis of the augmentations of the electricity and magnetism produced by the rotations of the armatures. As the armatures revolve they become slightly magnetized in their passage between the poles of the electro-magnets, generating weak currents in the insulated wires surrounding them. These currents are transmitted by means of a commutator through the wires surrounding the electro-magnets, so as to increase their magnetism, until, by a series of actions and reactions of the armatures and electro-magnets on each other, the magnetism is exalted to the highest degree of intensity and the most powerful currents of electricity are produced. A small fraction of the current thus produced is sufficient to sustain the power of the electro-magnets, while the major portion of the current produces the light. The machine on board the Comet is 28 in. high, 34 in. in length, and 21 in. in diameter. Its weight is 11 cwt. About 4-horse power is required to drive it a velocity of 600 revolutions per minute, and this driving power is obtained on board the Comet from the fly-wheel of the small engine that raises and lowers the 18-ton gun and its platform. At this velocity the current will fuse an iron wire 6 ft. long and 0.05 in. in diameter, and will burn carbons ½ in. square. In this machine the alternating current is used for producing the light, past experience in lighthouse illumination having proved it to be greatly superior to the direct or continuous current, since it has the important advantage of consuming the carbons equally, and thus always retains the luminous point in the focus of the optical apparatus used in connection with the machine. The alternating current also dispenses with commutators, and the destructive spark on the rubbing surfaces is also avoided when the light may be accidentally extinguished, or when the circuit becomes broken from any other cause. Copper wire conductors are laid from the machine along the Comet's deck, from the position of the machine over the engine-room to the fore part of the vessel, for the transmission of the electric current to the apparatus where the light is regulated and projected from. All the arrangements on board the Comet in this respect have

been made to render the light available for naval purposes whether as a torpedo boat detector or otherwise, and with this view a simple mechanical regulator arrangement, worked by the hand, has been substituted for the delicate mechanism by which the carbon poles have hitherto been automatically adjusted. The carbons as they consume are made to approach each other by means of right and a left-handed screw, the screws being made to act independently of each other, so as to allow of the adjustment of the carbons to the focus of the optical apparatus used for projecting the light. The regulator with its carbon points is placed in the focus of a catadioptric lens, which parallelizes the divergent rays of the light into a single beam of great intensity. The lens, with the regulator, is pivoted horizontally and vertically on the top of a short iron column fixed on the forecastle bulwarks of the Comet. The box holding the lens and regulator with the carbons is thus well elevated above the bows of the vessel, and the beam of light, by the action of a quick screw adjustment, may be directed to every part of the horizon and cover any object within the vertical angle of its range. As the carbons only require regulating once in two or three minutes, this is effected by the man in charge without any interuption in the movement for directing the beam of light.

Such is the "Wilde electro-magnetic induction machine," and the nature of the work it did on Thursday and Friday nights, so far as it is necessary to enter upon in a paper written only to explain its powers as an electric light for the navy. It is almost superfluous to observe, however, that any ship of war having one of these machines on board would find its light-producing powers of inestimable value for other purposes than its employment as a torpedo vessel or boat detector in an ancorage at night. The cost of working such a machine is a not unimportant item in any official consideration of its usefulness. Mr. Wilde, in his official communications with the Admiralty, has estimated the cost of producing the light from his machine on board the Comet, exclusive of the driving power obtained from the vessel's engine-room, at only 4d. per hour.

RIVER POLLUTION—THE REPORTS OF THE COMMISSION.*

From "The Building News."

The author stated at the outset that in this paper he should deal only with two reports, viz., those of the Royal Commission of 1865, which treated of the Thames and Lea. No more momentous questions ever engaged the attention of a Royal Commission than the pollution of rivers and the water supply of the people, and it was to be deplored that so much labor as had been bestowed by the Commissioners had borne so little fruit. It was to be hoped that the Government would soon find time to deal in a practical way with such important questions. It had been said that we ought to thank Providence for the fact that wherever there was a large town, there also was provided a river close by. This was a very handy arrangement for getting rid of the town sewage, even at the cost of poisoning the people living in towns lower down the stream; although one fact brought out by the report of the Commissioners in connection with this part of the subject was worth noting, viz., that except in a few cases, however bad the state of a running river might be, we were not able to trace directly any outbreak of disease to it. The cesspool was indeed the unfailing source of every sickness, as though Death itself were condensed therein; but the foul river seemed to act more gradually, and rather by lowering the health of a district than by causing epidemics. Mills and manufactories made the same use of the rivers as the towns, and each loudly blamed the other for the nuisance. The Royal Commission of 1865 was addressed to Robert Rawlinson, John Thornhill Harrison, and John Thomas Way, Esquires, and directs the Commission to inquire "How far the present use of rivers or running waters in England for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented without risk to the public health or serious injury to such processes or manufactures, and how far such sewage and refuse can

*A paper read before the Civil and Mechanical Engineers' Society by W. F. Butler.

be utilized or got rid of otherwise than by discharge into rivers or running waters, or rendered harmless before reaching them; and also for the purpose of inquiring into the effect on the drainage of lands and inhabited places of obstructions to the natural flow of rivers or streams, caused by mills, weirs, locks, and other navigation works, and into the best means of remedying any evils thence arising?" The letter of the Home Secretary suggested that the inquiry should include selected river basins, illustrating different classes of employment and population, and named six subjects of inquiry, viz.: (1) The Thames Valley, as an example of an agricultural river basin, from which, after extensive pollution, is mainly derived the water supply of the metropolis; (2) the Mersey Valley, as an example of a river basin most extensively polluted by all kinds of manufacturing refuse; (3) the Aire and Calder Basin; (4) the Severn Basin, as connected with the great seats of the iron trade; (5) the Taff Valley; (6) a river basin comprising a mining district in Cornwall. The subject of water supply was added in consequence of a letter from Mr. Charles Neate, M. P., to the Home Secretary. The first river, therefore, which claimed the attention of the Commissioners was the Thames. The length of the Thames is 201 miles, and its basin extends its greatest dimension east and west from Cirencester, in Gloucestershire, to Shoeburyness, in Essex, and its greatest breadth, north and south, from Priors Marston, in Warwickshire, to Fernhurst, in Sussex. The area of the entire basin is 5,162 square miles, or 3,303,680 acres. The annual rainfall about Thames Head is from 27 in. to 30 in., and in London about 25 in. The tributaries of the Thames above Hampton are, on the north side, the Churn, Coln, Windrush, Evenlode, Cherwell, Thame, and Colne, while from the south the river receives the waters of the Ray, Cole, Ork, Kennet, Lodden, Wey, and Mole. On the main stream of the Thames above Hampton there are 217 towns, villages, and hamlets, with a population, in 1861, of 172,120. There are also 69 mills, while on the tributaries there are 784 towns and other places, having a population of 715,968, with 199 mills. The tributaries below Hampton are, on the north, the Yedding, Brent, Lea, and Roding, and on the south, Hog's Mill, Wandle, Ravensbourne, and Darent. There are also eleven canals joining the Thames at various points downward to Gravesend. The dry weather flow of the Thames is almost entirely spring water, there being neither lakes nor marshes to store up flood water. Were there such natural reservoirs of sufficient size, it is probable that the floods to which the Valley of the Thames is subjected would be in a great measure prevented. The dry weather flow of the Thames at Wolvercot, three miles above Oxford, is estimated to be about 50,000 gallons per minute, which quantity is increased in ordinary floods to about 223,000 gallons, which was again increased, after five days' rain, during which there fell 1.456 in. of rain, to about 505,000 gallons. Owing to the neglected state of the river, floods, especially those which come in summer, are very destructive. Proper attention to weirs and locks, the construction of sufficient land drains parallel to the river, and the formation of a system of embankments where required, would go very far to render floods harmless. The Thames has been a navigable river time out of mind, and before railways were made a large trade was carried upon it. Now, however, the navigation of the Upper Thames is at an end, for the river is full of shallows and islands, the banks are neglected, and the locks will neither open nor shut. Between Oxford and Lechlade all navigation may be said to have ceased, not altogether from the cause usually assigned, viz., railway competition; for the Lea is a river exposed to much keener railway competition, and was never in a more flourishing condition. The locks on the Upper Thames are in a ruinous state, nor are there any funds with which to put them in order. The weirs, too, are frequently owned by the millers, who, when they want water, fix boards to the weir to increase its height, of course at the risk of flooding the adjacent land. Many of the weirs, too, are totally inadequate to pass the requisite volume of water in flood times, so that the river is choked at these points, and flooding is a natural result. Any form of curved weir does not seem to be adopted, and both locks and weirs are old-fashioned and quite worn out. There are, as before stated, 61 mills on the main stream of the Thames, several of which are paper mills, causing a great deal of pollution in the river. Many of the weirs belong to these mills, and though the millers are prohibited from raising high-water mark above a certain fixed level, yet,

as there seems to be no one to enforce the prohibition, it is not always obeyed, and from this cause flooding and injury to land results. The unchecked growth of weeds, especially in the Upper Thames, is a serious evil. Few persons ever take the trouble to cut them, and if they do, no one seems to think of removing the cuttings from the river; they are simply left to float down and choke the next weir, or clog the next mill's hatches or wheel. In many cases they help to form aits or banks, upon which, when sufficiently large, the nearest riparian proprietor or miller plants osiers for his profit; and so the numberless islands are continually increasing. The navigation of the Thames below Teddington has not undergone the same vicissitudes as the river above that point; nevertheless, there are many remarkable facts connected with it. For instance, the removal of Old London Bridge lowered the water at Richmond 1 ft. 4 in., or, as one witness stated, 3 ft., and the dredging carried on in the pool tends still further to diminish the depth of water higher up, so that navigation can hardly be carried on above Putney at low water. From this cause, and from the great extent of foreshore which is left dry at low water, a cry has arisen for a lock and weir at Isleworth; but there are several objections to this. If the proposed weir were erected, it must shut out the tide for a length of about five miles, which would cause a serious diminution of the scouring power of the river below the weir. This was not to the same extent the case with the Teddington weir, as the tide would seldom flow above this point. Already the scour of the river through London is not too great, as may be seen by looking at the extensive deposits of mud which are forming beside the new Embankments. Any diminution of the volume of water might have the most serious consequences. Again, by the raising of the water level, a large tract of valuable land would be permanently inundated, and the drainage of the whole district seriously affected. One of the witnesses stated also that one result of the proposed weir would be to leave the river nearly dry below it to Putney. It seems pretty certain that if a lock and weir were erected at Isleworth another would be required about Putney, which would shut out an additional seven miles of tide water. These weirs must be full-tide weirs, for if they were so constructed as to allow of a portion of the tide passing over, there would be such a deposit of mud from the still water as would require constant dredging. One witness stated that he found even now a deposit in the still parts of the river near Kew, forming at the rate of 1 in. per month. It would be possible so to lower the bed of the river between London Bridge and Teddington, by dredging, as to insure sufficient water at all times for navigation purposes; but if this were done, more and more of the foreshore would be left exposed at low water. Altogether, the Thames between London Bridge and Teddington weir affords a very nice problem for the Engineer to the Conservancy to solve. Possibly the difficulty might be overcome, though at a great expense, by canalizing a portion of the width of the river, leaving the remainder for the tide and flood waters. The canal, when the land would admit, might be carried inside the river bank. Of course this canal could only be used for through traffic, and for that intended for one side. Barges going to or from the wharves on the other side must still pass up the old channel. Mr. Butler then passed on to consider the numberless pollutions to which the river is subjected, as detailed in evidence before the Commissioners. As this portion of the subject has already been very fully discussed in the "Building News," we need not here say more. Land drainage, sewage irrigation, and the abstraction of large quantities of water from the river for drinking and manufacturing purposes, are all topics which came within the scope of the Royal Commissioners—who also recommended that the anomalous and mysterious body, known as "Thames Commissioners," should be abolished, and that the sole jurisdiction over the river be vested in the Thames Conservancy. Passing on to consider the River Lea, it appeared that though is is the source of a very large proportion of the potable water of the metropolis, it is frightfully polluted. The navigation, however, is exceedingly well cared for by a body called the River Lea Trustees, who exercise jurisdiction over the river. The Lea, although it has to contend with the Great Eastern Railway running alongside nearly all its length, increases its traffic year by year. The locks and other navigation works on the Lea were laid out by Smeaton between 1770 and 1780, and that celebrated engineer designed a great number of locks between the Thames and the

level of Hertford Pond, with a total rise of 119 ft. above Trinity high-water mark. There are also six extra flood and tidal locks, or stop-gates. The locks on the Lea are thought to be among the first constructed in this country. The locks as constructed by Smeaton were made with waist, platforms, and foundations of timber; but the upper and lower recesses for gates were of brick, with piling between. The piles were about 16 ft. apart, the spaces being filled up with horizontal camp-sheeting. These locks had a maximum of 3 ft. draught of water, and a rise of about 4 ft.; their width was 13 ft. and the total length from centre to centre of the gates was 96 ft. Having described the course and tributaries of the Lea, and given other interesting and valuable information, Mr. Butler brought his paper to a close.

THE STROPHOMETER OR SPEED INDICATOR.*

By T. A. HEARSON, Esq., Assistant Engineer R. N., Associate.

From "Iron."

Nearly all engines, and especially those which propel ships, are subject to great and incessant fluctuations of speed, and it is desirable to have an instrument which will indicate by a pointer on a marked dial, not the momentary but the mean rate of revolution of the engine, or the number of turns which would be counted in a minute. Attempts to ascertain the exact velocity of rotation by the amount of deflection produced in a spring, by the centrifugal force generated in a revolving weight, have naturally resulted in an excessive oscillation of the pointer rendering the machine almost useless. Before we can obtain a valuable indication by these means, it is necessary that the weights in which the centrifugal force is generated should revolve with an uniform velocity equal to the mean speed of the engines.

In the strophometer, fly-wheels driven by friction are used, the action of which is to eliminate the smaller and more frequent variations of speed which are only momentary, and obtain an almost constant velocity of rotation. Its construction and manner of working is this.

First, there is a steel spindle, having a groove cut along the upper part of its length, and secured firmly by a nut at the bottom to a bracket, which may be fixed in any convenient part of the engine-room, ship, or factory. On the lower part of the spindle a steel-bushed pulley revolves freely, a gut being led round it from the shaft, or any revolving portion of the machinery. Resting on the pulley and running freely on the spindle, is a steel-bushed fly-wheel, a thin steel washer with a large bottom and small top being placed between, so as to give a small bearing surface for the fly-wheel. The under face of the fly-wheel is recessed, and into the recess there project up from the pulley two studs, having one of the ends of a pair of chains connected to them; the other ends fly out by the centrifugal force against the inside of the rim of the fly-wheel, and act frictionally thereon so as to make the fly-wheel revolve. Similarly, chains from studs on the lower fly-wheel impart motion to another steel-bushed fly-wheel, also running freely on the spindle, the bosses being separated by a thin steel washer. With these driving arrangements the inertia of the fly-wheels will prevent them from being too easily affected by the changes of speed which are not persistent; and if the small variations are not sufficiently obliterated by the lower fly-wheel, they will be more completely so by the upper one.

Surrounding the spindle above the upper fly-wheel is a helical wire spring, the bottom being fastened to the fly-wheel and the upper end to a boss or collar, which may slide up or down and revolve freely round the spindle. The boss is also connected to the fly-wheel by two pairs of jointed links. These links carry balls on their middle joints, and the action of the centrifugal force in moving these balls outwards, causes the boss to be the more drawn down, and the spring to be more compressed, the greater the speed is. The movement of the boss is communicated to the pointer by means of a bent steel wire (which nicely fits the groove and clasps the upper and lower edges of the boss) jointed to a light

* A paper read before the Institution of Naval Architects.

rod with a rack on the upper end gearing into a small pinion on an arbor carrying the pointer, which sweeps over a marked dial carried by the bracket on a spindle.

The amount of the frictional driving power produced by the chains increasing with the increased velocity and centrifugal force, will be always a little greater than the increasing resistance to rotation, which the fly-wheel receives from the air—the constant driving friction of the boss being made sufficient to overcome the constant resistance of the friction of the spindle. The difference between the driving power and the resistance is thus very nearly constant for all speeds, and bears some proportion to the inertia of the fly-wheels, depending on the amount of the fluctuation of speed the engine experiences, and the steadiness required in the pointer. There being no permanent slip, the upper fly-wheel is made to maintain an almost uniform speed equal to the mean speed of the pulley; and thus a steady indication is obtained. The pulley and fly-wheels may, when desired, be joined together by a pin. Then the fly-wheel will rotate exactly with the engines, and the fluctuations indicated by the pointer may be observed. It will be found that the mean position of the pointer is the same as it would attain when the pin is removed. By this experiment the amount of chain required to drive the fly-wheel is determined. If more than is necessary be used, the needle will occupy the same mean position, but will oscillate about it more or less. If there be less chain than required, the resistance being in this case greater than the driving power, the fly-wheel will fail in attaining the mean speed of the pulley, and the pointer will not reach the mean position before found.

One of these strophometers has been at work in H. M. S. Agincourt for about nine months, enabling the engineer to tell at a glance and within a quarter of a revolution, the speed of the engines. When the ship in a rough sea is pitching a great deal, and the engines experiencing very great fluctuations of speed, the pointer may be seen to move slowly about the mean position each way within the limits of half a revolution; a steadiness sufficiently exact. The want of a machine of this kind was most urgently felt in ships of war when steaming in company with others. To keep accurate station one with another, a most careful and frequent adjustment of the speed of the engines is necessary; performed by opening or closing the admission-valve a trial amount, and ascertaining the error, if any, by counting with a watch, and then correcting it. This, when often repeated, is a tedious process, and doubly so in ships with twin-screw engines. When performing steam evolutions the frequent alterations of speed required renders this instrument extremely valuable. It shows the change of speed with the change of steam pressure, the throttle valve being unaltered; and the change of speed due to the change in the force of the wind, or the set of the sail; the steam pressure being constant. The effect on the speed of more or less injection water is also shown by it. It enables one to note the speed at the instant of taking an indicator diagram, and so the correct indicated horse power can be determined. It may be fitted on deck as well as in the engine-room, that the officer on watch as well as the engineer in charge may know the speed of the engines. Although being particularly adapted to indicate the speed of marine engines, it may be advantageously employed for other purposes.

It may be used to indicate the speed of a ship in the following manner: A small screw being fitted outside, and at a little distance from the side of the ship, so as to turn with the pressure of the water due to the onward movement; and a light gearing being led from it to a machine of this kind in the ship; the many and great fluctuations in the speed of the screw, produced by the waves, and the rolling, pitching, and yawing of the ship being deleted by the machine, the speed of the ship in knots per hour may be indicated by a pointer on a suitably marked dial. It can be designed so that the screw may be lifted out of the water in weather rough enough to endanger its safety. The strophometer would be useful in locomotives, for telling the speed of the train in miles per hour. The fluctuations in this case being small, one of the fly-wheels may be dispensed with. The machinery used for spinning and weaving should, to work efficiently, keep an almost constant speed. The application of this instrument would test the presence or absence of this requirement. Here the range of speed being small, the whole of the dial should be utilized by having a small pinion. Each revolution may be subdivided, and the speed indicated with very great accuracy.

HYDRAULIC MOTORS.

From "The Engineer."

There can, we think, be little question but that the use of hydraulic power as a motor is daily on the increase, and that as its merits and capabilities become better understood and developed, the ratio of that increase will be considerably greater in the future than it has been even of late years. The whole subject is one which, as our readers know, has not in any wise escaped our attention as regards the general principle connected with the theories involved, and the illustrations and descriptions which from time to time we have given of the different machinery, inventions, and appliances that have been proposed and tried with certainly varied success, will have kept before those same readers a more or less general view of the concurrent history of the adoption of hydraulic power as a motor. It is scarcely necessary for us to point out, or, indeed, even to refer to the different forms which have been given to hydraulic machines by their inventors. The ordinary overshot, breast, and undershot wheels so common at one time in this country are of course familiar to every one; it is not, however, of such applications as these that we propose to treat, but rather of those instances in which water pressure as a motive power has been adapted to engines and machinery. We do not at all pretend to give even a sketch of the history of these, but we find in looking through some old notes that in 1803 Trevithick erected at the Alport Mines an engine in which the water was admitted first upon one face of the piston and then on the other, the inlets and outlets being opened and closed by two smaller pistons operating at the sides. This machine worked continuously during forty-seven years—*id est*, until the year 1850, when it was removed on the abandonment of the sett. We find, too, that at the same mines Mr. Darlington erected a water engine having a cylinder 50 in. in diameter and a 10 ft. stroke. In this case, the cylinder, the piston, and pump-rod, being in one continuous piece, was placed directly over the pit, the pressure on the piston, coming from a head of water 132 ft. in height, equalling about 58 lbs. to the sq. in., or, say, 50 tons on the whole area. With a plunger 42 in. in diameter, water was raised at the rate of 5,000 gallons per minute from a depth of 22 fathoms, the water for the motive engine being in this case admitted on one side of the piston only through cylindrical valves, allowing a full flow for seven-eighths of the stroke, when they began to close, and a small valve then opened to allow sufficient water to pass to complete the stroke. The same gentleman afterwards erected another engine nearly similar in its general construction to this, but working under a pressure column 227 ft. in height. The average speed of this latter machine was 80 ft. per minute, but this could be run up to 140 ft. per minute.

Sir William Armstrong, in addition to his well-known water cranes, has, we believe, made use of water pressure from natural falls to produce rotary motion by means of double cylinders and pistons with slide valves, in some degree similar to those of high-pressure steam engines. There is, however, a difficulty about working any of these machines; for although the absence of any sensible elasticity in water renders motion produced by it in engines susceptible of perfect control, yet that same inelasticity is apt to cause sudden shocks and blows to the moving parts of water engines, if they be constructed on the same principles as those for such elastic fluids as steam or air. This said difficulty has, however, been in great measure overcome by the use of relief valves, or their equivalents. Another well-known mode of utilizing hydraulic power is the turbine; the works at Bellegarde, which are now being illustrated in our papers, constitute an excellent example of the most recent application of this form of hydraulic mechanism. Our purpose at present is to direct attention to proposals and arrangements for a very extended application of hydraulic pressure, which have been put forward by Mr. R. H. Tweddell, whose system of riveting, both by fixed and movable machines, we have already noticed. This last proposition deserves consideration, the more especially since the general tendency of practical constructors is certainly to concentrate operations in one spot, thus rendering area of manufactory so great that there arises a certain difficulty in distributing the central power by shafting or gearing. In such cases as these, Mr. Tweddell proposes that water-pressure

mains shold be laid down on a regular plan, and branches carried therefrom, as required, to the different individual tools—such as planing and slotting machines, and the larger class of lathes; under which arrangements there would be very considerably less loss of power in transmission than that sustained in a system of shafting, belting, or gearing; for, in fact, it only involves the friction of the packing in the pumps, the accumulator, and the water in the pipes, which has been found to be little over 1 per cent. On this head, however, it may be remarked that for the smaller classes of rotary machines Mr. Tweddell is rather in favor of the use of shafting, which, he says might probably be advantageously driven from the pumping engines, in which cases he would recommand the use of an engine of Brotherhood's three-cylinder type, the adoption of which to such purposes has already been under consideration.

It will be seen from the foregoing that the idea of using hydraulic power as a general motor is a sufficiently extensive one, inasmuch as it embraces in a whole the supplying of power to almost every variety of machine or tool, and that in a manner which would render it always available, and that, too, with economy; for the power once stored up continues at the disposal of the operatives without any further expense, whilst if steam be the directly acting agent, its maintenance at a certain pressure, so as to be equal to the task requiring performance, is a matter of charge in some form or other, and, especially when the power needed is only intermittently used, entails considerable waste and expenditure.

There is unquestionably as yet a great deal to be done in the development of hydraulic machinery; but we venture to think that infancy is the infancy of a giant, and that by and by, when we come to see its strength put forth and its great usefulness demonstrated, we shall feel how much our thanks are due to the pioneers whose investigations and researches are daily contributing towards such results.

CONSTRUCTION OF CONICAL ROOFS.

From "The Builder."

On a previous occasion we reported briefly the discussion which took place at the Royal Institute of British Architects after the reading of Mr. Scott Russell's paper on the "Central Dome of the Vienna Exhibition Building." We now add in full Mr. Scott Russell's reply, as containing much interesting matter:—

I will now endeavor to answer the points on which you have asked for information, as concisely as I can. I am afraid when I say anything it may have the appearance of being too dogmatic, but I hope you will not accept it in that way. I feel deeply grateful to gentlemen who have deduced the points and exceptions and difficulties which they have done, because in answering them I think I shall give them the conviction that the cone possesses greater merit than I could have satisfied them it possessed if they had not been good enough to make these objections. I will now run through the matter as quickly as I can. In the first place, permit me to say that almost every one of the suggestions you have made, as to the alteration of the cone, and the different views of its theory, are perfectly true; and allow me also to say, I have confined myself in that article to the pure cone, because if I had gone out of the pure cone into the region of new structures, the quantity I could have laid before you is so enormous, that you would have been lost in a maze of confusion, as I was; and I had enormous difficulty in selecting out of the multitude of applications of principles of this kind the form of the cone at Vienna. You would imagine men of taste would be in love with the beautiful spheroidal form, and would not take the strictly straight cone when they might have the more beautiful spheroidal form. I will tell you how I came not to adopt it: I drew it out and discussed its peculiar qualities, and it was only the peculiar state of conditions which led me to adopt this form, which I think is not so beautiful as if I had made it spheroidal. A multitude of questions arose. It has been properly said, that time is a great element in practical construction, and engineers and architects are often obliged to abandon what they wish to do, by want of time. Now, want of time and want of money are two things against the

spheroidal dome. I will tell you why. The conical form has enormous advantages in construction. All the iron plates are plates of single curvature—straight one way, gently curved the other. What is the consequence? We can put between them rollers, we can manufacture them by hundreds, and bring them out ready for the building. Take a surface of double curvature; you have to heat it in the fire, you have to cut its edges to a peculiar surface, you probably encounter great difficulty requiring much time to surmount, and if you have to do it, it is always badly done; whereas my cone can be manufactured by machinery, on the most simple but still most perfect mathematical principles. The reason why I prefer an absolutely straight cone to the cone with curvature is this: Mr. Penrose has touched upon the point. I have shown you that all my cone longitudinally is in compression—that all my cone circular-ways is in tension. Now a straight column under compression is much stronger than a bent column, and therefore that part of the cone in compression is far stronger if it is straight. The next point has been very properly stated, viz., that the ribs of this cone are very much deeper than you would imagine, from investigation of the cone itself. You are correct. The ribs of the cone, as originally designed, were much shallower than they are now. Why were they altered? Simply for the reason Mr. Crace has stated, that all the conditions of the original design were altered. The cone was made for being put upon masonry or brickwork, which was to have been carried out to the edge of the cone, and the cone was to have been set upon that. Then the chance of the cone changing its form was very small, and these ribs or rings which have a peculiar function with reference to columns had no such functions when resting on masonry, and therefore were very small. These girders were enlarged, because it was agreed, from circumstances of time, to sweep away the whole of the solid foundation; and one fine morning I was told "you are not to have a wall to put the cone upon; therefore, you must stick it upon iron columns in the best way you can." Then to arrange the iron columns to carry the buildings, but to carry the cone, and that resting upon solid masonry foundations, are two things totally and entirely distinct. To sum up the whole question with regard to cone and girder, permit me to say, that these girders were by some people thought very strong when they were put up. Only there came a little wind after they were put up, and people who went there saw a slight vibration in the wind which satisfied them that the girders must come down if the weather were at all tempestuous. It was only after they got the cone to rest upon, that they became part of the cone. It was only then they acquired any strength at all. What they have is great strength in their place; out of their connection with the cone they have none. If you take the great thickness of the girder, which is more than double what was designed, and then look at the length of it, 166 ft.; and then if you take the depth, not at the extreme end, but at the centre of gravity, where the strength is, you will find that these beams, which you think strong, are hopelessly weak to carry any structure, and then you will see that the beams had no strength till they became a part of the building. Coming more to the question of cones made of homogeneous metal, I may state that about three years before the opening of the Exhibition of 1851, I discovered that the cone was the successful structure which I have endeavored to show you it is; and it is a curious fact that I owe to you, and the reception which you gave to me in some papers I read, the original ideas of this cone.

I read to you some thirty years ago a paper, describing a principle by means of which the greatest number of spectators could be arranged in a large building, so that they should all equally well see any spectacle they were brought together to see. I then, I dare say, satisfied you that you could make a building in which 10,000, 20,000, or 100,000 people could have sat together, all witnessing the same spectacle, and each one thinking he had got the best place in the room. That was solving a difficult problem, but it was leading you on to the construction of very large buildings with very large audiences. Twenty-five years ago I read you another paper, which you discussed with the same friendly energy as you have this,—viz., on the question how to combine the largest number of people in a building so arranged that all sounds should reach the ears of those present in the most perfect and distinct manner. I also tried to explain certain principles by which echoes and influences which impede sound, and impede the clear hearing of separate

sounds, might be removed. I hope I persuaded you that a building could be made in which 5,000 people could confortably listen to a single speaker, or an audience of 25,000 people could comfortably and agreeably hear a musical performance, but at the same time I know you did not believe that such buildings were necessary. But such buildings now have become so. You have had the Exhibition building of 1851, in which 100,000 persons were collected at one time, and you have had arrangements for the performances of music by orchestras of 3,000 persons, which have been listened to by 25,000 persons. [*A Voice.*—You cannot hear.] I have a deaf ear, but I could hear confortably with my deaf ear; and the orchestra which you have now in the Crystal Palace has carried out in the most perfect manner the theory I then gave you. I call attention to this theory of seeing and hearing, because it compelled me to think how I should roof this large building, and thinking over the problem you discussed, I arrived at this fact, "that if you are to have large amphitheatres to hold many thousands of people to view spectacles in London, in the way that the Romans did, you must make them with a cone, and I have invented this cone to cover your great buildings when you are pleased to build them, and if you make those great buildings in London—and you will have to do it, for buildings are growing larger every day—I expect you young men here will have to make roofs, not of 360 ft. span, but of 720 ft., conical roofs, and after that you will go on to make them 1,080 ft., and perhaps you will not go farther in your lifetime, but I undertake to say the task will be easy, and the cost what in those days will be called moderate."

Coming now to this small cone. The moment the idea had not only occurred to me, but was proved by investigation to be an idea in which you could use material much more economically than any other form I knew, I immediately developed the other form of cone to which you alluded. I saw that in my kind of building it would be possible to cut away all the dead matter of the cone, and put it into skeleton; and many years ago, in conjunction with an eminent member of your own profession, I designed a building in which all you have said was done: in which we throw away the entire homogeneous cone, in which we take away those trusses of which you speak, which are as old as wood construction. I have seen in the Rhenish countries the cone with wooden roofs applied to those semicircular Romanesque buildings, which for a time on the Rhine were competitors with Gothic architecture. I think I have seen wooden cones 250 ft. in diameter. In like manner you use iron girders, and do what you cannot with wooden struts, and you make a truss which requires no useless beams, no wasteful doubling, which is a perfect cone like my homogeneous cone, but I have always called that a skeleton cone; and, therefore, when you get these two circumstances together, if you are wise, you use a homogeneous cone for all it is good for, and a skeleton cone for all it is not good for: as it is not where columns are inserted below; and, therefore, you add these additional struts at the point where the local strain requires it. If you construct a cone with large foundations and continuous walls you find a solid, homogeneous cone is the cheapest and strongest form. If you make it on a small scale, where enormous strength is not required, you find the skeleton cone will answer all your purposes, and you can fill in with glass or any material you like. I like a homogeneous cone for this reason,—there is not one atom of waste. In common roofs you have slates and wood. The slates and wood do not carry themselves, but are a burden upon the structure. I have a large cone which justifies the use of iron plates, a half or three-quarters of an inch in thickness. I take these plates and form a roof of them alone, and then we have only to rivet and caulk the cone properly: and I believe it would stand without repairs for 100 years, and with repairs for 200 years; but you can modify this to any extent, and yet preserve to a large extent the principle of the cone. A gentleman mentioned the Exhibition of 1851 as having an iron dome proposed for it. You may remember that in 1851 many architects and engineers met and designed a building for the Exhibition. That was somehow eclipsed by Sir Joseph Paxton's wonderful invention, but allow me to say that a spherical dome can only be truthfully made by making curves of double curvature to every plate, and there is no difficulty except that you have to put your plates individually into the fire, and have them all hammered into ultimate shape. But I will show you a way of converting my cone into a dome

at once, which was the very thing proposed in 1851. I would have built my cone in 1851: I had it all ready then. The cone I had ready was 400 ft. diameter. Why did I not? For this reason,—it happened I was one of the four persons who, with Prince Albert, originated the Exhibition of 1851. He insisted that I should be his secretary, and that I should be charged with the whole details of the Royal Commission. I had instantly to put all my plans into my pocket. I willingly assisted Sir Joseph Paxton to bring forward his. I told Mr. Henderson, Mr. Fergusson, and Capt. Fowke all about it, and they kept my secret, and nobody spoke about the cone till after Mr. Crace had prepared my designs for the Vienna dome.

About cones: I am glad to see the drawings of the cone which was then designed. That dome is what I would call a skeleton dome. First of all, I will show you an ugly dome, which I would (illustrating on board) make with a series of cones. If I were obliged to make a dome, and were ordered to make an ugly one, but retain, if possible, the same principle and the same economy which belong to my present dome, I would do it without incurring the difficulty of double curvature, in this way, by uniting a succession of cones of increasing taper. I should thus make what people call a dome. That you see is very ugly; but if I wanted to reduce the ugliness of it, then I could reconcile these patches by a filling of wood or other material, and thus I should have got a cone which, geometrically speaking, one would call perfect and beautiful. Now, in like manner, I was delighted when Professor Kerr suggested that we might have a great number of buildings of that sort, and ever since I studied the cone I have been astonished at the small number of buildings of that sort which exist. I am astonished to see in your buildings and in ours, the waste of material you go to, when you might do without it. Suppose this to be an enormous square building; suppose you wanted to cover this with a roof. Why not make a parabolic roof? Make it a cone with four flat sides. Make it an octagonal cone, which you could do by cutting off the corners and putting in girders. Then you have no occasion for ties. Captain Fowke did that in some of his beautiful buildings at Kensington. You can make a series of structures, all self-contained, all without waste of material, and all under certain circumstances beautiful. Gentlemen have alluded to oval buildings. You find them immensely disposed to change their form, but there are remedies which consist of addition of material. You must put in material to counteract that tendency to change of form. I will now tell you a secret, which I am sure you will keep confidentially, and not allow it to go out of these walls. It was proposed to me, once upon a time, to put a conical roof over the ancient amphitheatre at Rome. That would have been an architectural desecration. I went to a friend, who was an architect, and asked him, "What would you advise? I do not like to refuse these people. I am fond of the cone, and I should like to see it carried out: but would it not be a barbarism?" My friend replied, "Don't do it." I wrote back that I would not do it; but I had gone into the calculation, and I found there would have been no difficulty in putting up a cone, moderately expensive, which would have preserved the building for 200 or 300 years.

A gentleman asked me whether I would like to take away all the columns, or a few of the columns in the Vienna building, and some of my friends have asked how the building is supported. I introduce that as an illustration of the difficulties I had to contend with. I was informed that my solid walls were to be taken away, and that I was to put my cone upon a series of iron columns. I was aware that they would press upon the margin of the dome very much. I did not expect the slabs of concrete put into the gravel of the Danube to give way; but, as earthquakes have taken place there, I argued the possibility of another earthquake happening after my crack building was put up. So I tried to make my cone stand even without continuous walls and foundations; and even in case of an earthquake coming, I considered what would happen if one foundation of a column gave way. "Very well," thought I, "if one foundation gives way, what must I do? I must carry the edge of the cone on the two adjacent columns, otherwise it will sway, and come down." Therefore I have put a strong rib all round the edge carrying the cone from one column to another. But two columns might have given way. When two or three columns give way, this beam becomes too long to carry the columns. What must I do? I

have only to keep a good thickness of metal in the cone itself, and then I should be extremely near having a catenary; that is, it is in one case a stretched chain. Take the case of three columns giving way. You will ask me, if three columns gave way, what will carry the cone above them? Professor Kerr did not like my terming the catenary an inverted arch. I do not think that is very strong. But it is not that which carries my columns. Think of the position. Three columns are taken away. Remember, the three corresponding columns on the opposite side are not taken away; therefore there is the weight of the cone on the other side balancing the preponderating weight on this side, and all united together by the catenary surface, out of which you can make any number of links you like. The chain is there, and this catenary I am now showing you is the catenary or parabola which has the whole of these columns hanging on this side, and the corresponding ones balancing them.

I have one final word to say, and that is, we have exhibited in a railway station not far from where we now are, a combination of engineering talent, with architectural skill, which is seldom witnessed, and there is no doubt the St. Pancras Station, with its roof of 220 ft. span, and its noble frontage, is a model of which your profession and mine may be proud. Only I must remind you that, if you want to go further, if you want much larger spans, you would find the circular ground plan has enormous advantages for a railway station, which no construction of railway stations hitherto appears to have had; and I recommend to your serious consideration the construction of a very large circular railway station with a domical roof. You will find it has enormous advantages. When you take the matter into consideration, you will see if you are required to design very large buildings in London, such, for instance, as on the great Embankment taken from the Thames, you will find a circular plan with a conical roof possesses infinite advantages, and if it were necessary to make buildings, such as railway stations, twice as long and broad, which I think would be foolish—but you must do it if your masters order it—all you have to do is put two circular roofs alongside one another instead of one oval, and the two close alongside will be much stronger than one oval roof equal to the area of the two.

THE ATMOSPHERE AS A VEHICLE OF SOUND.*

By JOHN TYNDALL, F. R. S.

From "The Engineer."

"On the Atmosphere as a Vehicle of Sound." At the instance of the Elder Brethren of Trinity House investigations on fog-signals were set on foot last May. They spread over several months, and Professor Tyndall embodied the scientific results of this inquiry in his communication to the Society. It is a remarkable fact in connection with this subject that, while the velocity of sound has been the subject of refined and repeated experiments, it is almost certain that, since the publication of a celebrated paper by Dr. Derham in 1708, no systematic inquiry has been made into the causes which affect the intensity of sound in the atmosphere. Derham's results, though obtained at a time when the means of investigation were very defective, have apparently been accepted with unquestioning trust by all subsequent writers; a fact which may be in some part ascribed to the *à priori* probability of his conclusions. Dr. Robinson, relying apparently upon the first-named authority, says, "Fog is a powerful damper of sound," and he gives us physical reason why it must be so. "It is a mixture of air and globules of water, and at each of the innumerable surfaces where these two touch, a portion of the vibration is reflected and lost." "And," he adds, "the remarkable power of fogs to deaden the report of guns has often been noticed." The same authority, as quoted by Sir John Herschel, says that "falling rain tends powerfully to obstruct sound." Falling snow also, according to Derham, offers a more serious obstacle than any other meteorological agent to the transmission of sound. All these generally accepted notions Professor Tyndall came to upset. His observations, both during the Trinity House inquiry and on the occasion of the

* A paper before the Royal Society.

recent dense fogs (December), show that the generally accepted opinion as to sound in its relation to the atmosphere requires a careful revision. The first-named investigation was begun on the 19th of May, 1873. Gongs and bells were excluded from the experiments in consequence of their proved inferiority to other instruments of signalling. They were carried out with trumpets blown by powerfully compressed air, with steam whistles, guns, and a steam syren, associated with a trumpet 16 ft. long. Daboll's horn, or trumpet, has been highly spoken of by writers on fog signals. A third order apparatus of the kind was reported as sending its sound to a distance of from seven to nine miles against the wind, and to a distance of twelve to fourteen miles with the wind. The experiments were made with an improved instrument by Holmes of the first order. This instrument on one occasion became useless as a fog signal at three miles distance. At four miles, with paddles stopped and all on board quiet, they were wholly unheard. On the same occasion, at a distance of two miles from the foreland, the whistles became useless. The twelve o'clock gun, fired with a 1 lb. charge at Drop Fort in Dover, was well heard on the same day when the horns and whistles were inaudible. On the 20th of May Professor Tyndall said the permeability of the atmosphere had somewhat increased, but the steam whistle failed to pierce it to a depth of three miles. At four miles the horns, though aided by quietness on board, were barely heard. The superiority of the 18-pounder gun, already employed by the Trinity House as a fog signal, over horns and whistles, was on this day so decided as almost to warrant its recommendation to the exclusion of all the other signals. The atmosphere evidently showed itself capricious. Within the limits of a single day, even within a single minute, the air as a vehicle of sound underwent most serious variations. On July 1st an interval of twelve hours sufficed to convert the acoustically clear atmosphere into an opaque one, for on the following day even the horn sounds which were heard at a distance of ten and a half miles on the previous day could not be distinguished, with paddles stopped and all noiseless on board, further than four miles. The acoustic imperviousness of the 3d of July was found to be still greater than that of the 2d, while the optical purity of the day was sensibly perfect. The cliffs of the Foreland could be seen to-day at ten times the distance at which they ceased to be visible on the first, while the sounds were cut off at one-sixth of the distance. At 2 P. M. neither guns nor trumpets were able to pierce the transparent air to a depth of three, hardly to a depth of two miles. This extraordinary opacity was proved conclusively to arise from the irregular admixture with the air of the aqueous vapor raised by a powerful sun. This vapor, though perfectly invisible, produced "an acoustic cloud" impervious to the sound, and from which the sound waves were thrown back as the waves of light are from an ordinary cloud. The waves, thus refused transmission, produced by their reflection echoes of extraordinary strength and duration. On October 8th, a steam syren and a Canadian whistle of great power being added to the list of instruments, a boiler had its steam raised to a 70 lbs. pressure. On opening a valve the steam would issue forcibly in a continuous stream, and the sole function of the syren was to convert this stream into a series of separate strong puffs. This was done by causing a disc with twelve radial slits to rotate behind a fixed disc with the same number of slits. When the slits coincided, a puff escaped; when they did not, the outflow of steam was interrupted. Each puff of steam at this high pressure generated a sonorous wave of great intensity, the successive waves linking themselves together to a musical sound so intense as to be best described as a continuous explosion. The optical transparency of the air on this occasion was very great; its acoustic transparency, on the other hand, was very defective. Clouds blackened and broke into a rain and hail shower of tropical violence. The sounds, instead of being deadened, were improved by this furious squall; and after it had lightened, thus lessening the local noises, the sounds were heard at a distance of seven and a-half miles distinctly, louder than they had been heard through the preceding rainless atmosphere at a distance of five miles.

At five miles distance, therefore, the intensity of the sound had been at least doubled by the rain, a result entirely opposed to all previous assertions, but an obvious consequence of the removal by condensation and precipitation of that vapor, the mixture of which with the air had proved so prejudicial to the sound. A few

days later on, and during a gale, it was sought to estimate the influence of the violent wind. It was found that the sound of the gun failed to reach the experimenters in two cases at a distance of 550 yards to windward, the sound of the syren at the same time rising to a piercing intensity. To leeward the gun was heard at five times and might have been heard at fifteen times the distance attained to windward. The momentary character of the gun sound renders it liable to be quenched by a single puff of wind; but sounds of low pitch generally, whether momentary or not, suffer more from an opposing wind than high ones. Taking the fluctuations of the atmosphere into account, Professor Tyndall is of opinion that the syren, performing from 2,000 to 2,400 revolutions in a second, or, in other words, generating from 400 to 480 waves per second, best meets the atmospheric conditions. The observations made afloat in the steam-tug Palmerston showed that the syren had the clear mastery over gun and horns. On one occasion, with a high wind and sea, the syren, and it only, reached to a distance of six miles; at five miles it was heard through the paddle noises. Among the incidental experiences of the observing party may be mentioned, that the shelter of the Coastguard station at Carnhill enabled them to hear gun sounds which were quite inaudible to an observer out of shelter; in the shelter also both horn and syren rose distinctly in power, but they were also heard outside when the gun was quite unheard. As usual, the sounds to leeward were far more powerful than those at equal distances to windward. On a day of extraordinary optical transparency (29th October) the atmosphere proved the reverse of acoustic transparency. The gun on that occasion was the greatest sufferer. At first it was barely heard at five miles, but afterwards it was tried at five and a-half, four and a-half, and two and a-half miles, and was heard at none of these distances. The syren at the same time was distinctly heard. The sun was shining strongly, and to its augmenting power the enfeeblement of the gun sound was doubtless due. At three miles and a-half subsequently, dead to windward, the syren was faintly heard; the gun was unheard at two miles and three-quarters. On land the syren and horn sounds were heard to windward at two miles to two miles and a-half; to leeward at seven miles; while in the rear of the instruments they were heard at a distance of five miles. The 30th of October furnished another illustration of the fallacy of the notion which considers optical and acoustic transparency to go hand in hand. The day was very hazy, the white cliffs of the Foreland at the greater distance being quite hidden; still the gun and syren sounds reached on the bearing of the Varne light-vessel to a distance of eleven miles and a-half. The syren was heard through the paddle noises at nine miles and a-quarter, while at eight miles and a-half it became efficient as a signal with the paddles going. The horns were heard at six miles and a-quarter. This was during calm. Subsequently, with a wind from N. N. W, no sounds were heard at six miles and a-half. On land, the wind being across the direction of the sound, the syren was heard only to a distance of three miles N. E. of the Foreland; in the other direction it was heard plainly on Folkstone Pier, eight miles distant. Both gun and horns failed to reach Folkstone. The experiments demonstrate that there are atmospheric and local conditions which, when combined, prevent our most powerful instruments from making more than a distant approach to the performance which writers on fog-signals have demanded of them. Professor Tyndall's investigations have given us a knowledge of the atmosphere in its relation to sound, of which no notion has been previously entertained. This is the first time that audible echoes have been proved to be reflected from an optically transparent atmosphere.

The real enemy to the transmission of sound through the atmosphere has been proved to be not rain, nor hail, nor haze, nor fog, nor snow—not water, in fact, in either a liquid or a solid form, but water in a vaporous form mingled with air, so as to render it acoustically turbid and flocculent. This acoustic turbidity often occurs on days of surprising optical transparency. Any system of measures, therefore, founded on the assumption that the optic and acoustic transparency of the atmosphere go hand in hand must prove delusive. Observations made during the recent fogs add the force of demonstration to others recorded above, viz., that they possess no such power of stifling sound as that hitherto ascribed to them. Indeed the melting away of fog on December 13th was accompanied by an acoustic darkening of the atmosphere so

great that at a point midway between the eastern end of the Serpentine in Hyde Park, where a whistle was sounded, and the bridge, the sound possessed less than one-fourth of the intensity which is possessed on the day of densest fog. For more than a century and a-half congeries of errors have been associated with the transmission of sound by the atmosphere, and the subject certainly deserves all the attention Professor Tyndall has given to it. In regard to the instruments of the future this principle ought to be kept in view, that the source of sound be made so powerful as to be able to endure loss by partial reflection, and still retain a sufficient residue for transmission.

Of all the instruments hitherto examined, the syren appears to come nearest to the fulfilment of this condition, and its establishment upon our coasts would prove an incalculable boon to the mariner.

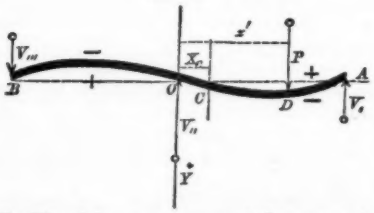
DISCUSSION OF THE APPLIED FORCES IN A DRAWBRIDGE.

By H. T. EDDY C. E., Ph. D., Princeton, N. J.

In order to compute the strains in the different members of a drawbridge covering two equal spans, it is necessary first to find the weight resting on each of its three piers. The weight on each pier is due to the live and dead load, and varies with every change in the position of the live load. The upward thrust of piers (which is equal and opposite to these weights), together with the live and dead loads, are the "applied forces" in the truss.

We shall first consider the truss to be a girder of uniform cross-section through its whole length, and afterwards take into account such modifications as appear necessary in applying the theory to a truss whose chords are of a variable cross-section.

Fig. 1.



In Fig. 1 is an exaggerated representation of the curvatures which the girder assumes under the action of a force P, when it is anchored to the piers A, O and B, which are immovably fixed in the same horizontal line.

Suppose that compression be considered positive and tension negative, then from the Fig. a conception may be obtained as to which of these is brought into play at different points along the upper and lower chords.

Particularly, it is necessary to notice the plane of contraflexure, C, where the moment of flexure and the horizontal strains in each fibre change sign and are therefore zero. Through C, vertical strains only, can be propagated, for vertical strains only, have no horizontal component.

Were the position of C known, to begin with, our work would thereby be greatly simplified, for it would only be necessary to find, from the principle of the lever, how much of P rests upon A, and how much hangs at C; but now we are obliged to find first the thrust up at A and B, and from that the position of C.

Let O be the origin.

x = distance from O of any cross-section of the girder by a vertical plane.
y = depression of any point in the cross-section caused by the weight.
x' = distance from O of the point of application of P.
x_c = distance from O of the plane of contraflexure.
l = length of one span.
M_x = moment of flexure at distance x.
M_o = moment of flexure at origin.
$M_c = O$ = moment of flexure at distance x_c.

A moment of flexure by which the girder is made to have centre of curvature below the girder will be considered positive; but when the centre is above, the moment will be negative.

Let us for brevity assume as proved, the relation given by Weisbach and other writers on the resistance of materials, viz.:

$$M_x = EI\frac{d^2y}{dx^2} = \Sigma[P(x'-x)]. \quad . \quad . \quad . \quad (1)$$

the middle member of which is the resistance which a girder opposes to flexure,

and the last member is the moment about the middle point of any cross-section whose distance from O is x, of all the forces applied to the girder between that point and its free end. For wrought iron E has been shown by experiment to be from 10,000 to 15,000 tons.

In any truss

Let I = sum of the moments of inertia of the two chords about the neutral axis of the truss.

Let I^1 = moment of inertia of upper chord,
and I_1 = " " lower "
about the neutral axis of the girder.
I'_g = moment of inertia of upper chorrd,
$I_{g'}$ = " " lower "
about their centres of gravity.
a', a_1 = area of cross-section of metal in the chords.
d = depth of truss.
d^1 = depth of rectangular cross-section of either chord.

$$I = I^1 + I_1 .$$

By Weisbach,

$$I^1 = I'_g + \frac{a'd^2}{4} = \frac{a'}{4}\left(\frac{1}{3}d'^2 + d^2\right).$$

But $d^1 = 0$ practically by reason of the flexible joints of the chords.

$$\therefore\ I = I^1 + I_1 = \frac{d^2}{4}(a' + a_1).$$

From this value of I it is evident that in a truss we must consider the effect of the variable cross-section of the chords in the different parts of the bridge. This we shall do after considering the case of the girder in which I is constant. But aside from the consideration of I, it is to be noticed that Eq. (1) applies with much greater accuracy to the case of a truss, than to that of an ordinary girder, for, first, all considerations respecting longitudinal shearing strain are at once disposed of by its flexible joints, and, second, the piers may be considered immovable, which the supports of a girder usually are not.

Eq. (1) is the general second differential equation of the elastic curve, from which by integration the curve belonging to any particular forces may be obtained.

I. Let us investigate the case represented in Fig. 1, of a single force P, positive down. Let the thrust up of the piers A, O and B, be V_1, V_2, and V_3 respectively, and positive up.

From equation (1), we have when x falls in A D, for the curve A D

$$M_x = EI\frac{d^2y}{dx^2} = -V_1(l-x) \quad . \quad . \quad . \quad (2_1)^*$$

For the curve O D,

$$M_x = EI\frac{d^2y}{dx^2} = P(x'-x) - V_1(l-x) \quad . \quad (3_2)$$

For the curve O B,

$$M_x = EI\frac{d^2y}{dx^2} = V_3(l+x) \quad . \quad . \quad . \quad (4_3)$$

From equation (4_3) by integration,

$$EI\frac{dy}{dx} = V_3\left[lx + \frac{x^2}{2}\right] + C.$$

If $x = 0$ $C = EI\frac{dy_0}{dx_0}$.

Let $t_0 = \frac{dy_0}{dx_0}$ = tangent of inclination of the curve at O to the axis of x

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = V_3\left[lx + \frac{x^2}{2}\right] . \quad (5_3)$$

Similarly integrate equation (3_2).

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = P\left[x'x - \frac{x^2}{2}\right] - V_1\left[lx - \frac{x^2}{2}\right] \quad . \quad (6_2)$$

Integrate equation (2_1).

$$\therefore\ EI\frac{dy}{dx} = -V_1\left[lx - \frac{x^2}{2}\right] + C.$$

If $x = x'$, $C = EI\frac{dy'}{dx'}$.

Let $\frac{dy'}{dx'} = t'$ = tangent of the inclination of the curve at D, to the axis of x.

$$\therefore\ EI\left[\frac{dy}{dx} - t'\right] = -V_1\left[l(x - x_1) - \frac{(x^2 - x'^2)}{2}\right] . \quad (7_1)$$

In equation (6_2) let $x = x'$ and (6_2) becomes

$$EI[t' - t_0] = P\frac{x'^2}{2} - V_1\left[lx' - \frac{x'^2}{2}\right].$$

Add this eq. to eq. (7_1)

$$\therefore\ EI\left[\frac{dy}{dx} - t_0\right] = P\frac{x'^2}{2} - V_1\left[lx - \frac{x^2}{2}\right] . \quad (8_1)$$

Again integrate (5_3)

$$\therefore\ EI[y - t_0x] = V_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \quad . \quad (9_3)$$

When $x = 0$ then $y = 0$ $\therefore$ no constant is to be added.

Integrate (6_2)

* We shall, for convenience, call A D curve 1, O D curve 2, and O B curve 3, and show which curve any equation refers to by a subscript numeral.

$$\therefore \text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'x^2}{2} - \frac{x^3}{2.3}\right] - \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right]. \quad . \quad (10_2)$$

Integrate (8_1) from $x = x'$ to $x = x$.

$$\therefore \text{EI}\,[y - y' - t_0(x - x')] = \text{P}x'^2\,\frac{(x - x')}{2} - \text{V}_1\left[l\frac{(x^2 - x'^2)}{2} - \frac{(x^3 - x'^3)}{2.3}\right]. \quad (11_1)$$

In eq. (10_2) let $x = x'$ then $y = y'$

$$\therefore \text{EI}\,[y' - t_0 x'] = \text{P}\left[\frac{x'^3}{2} - \frac{x'^3}{2.3}\right] - \text{V}_1\left[\frac{lx'^2}{2} - \frac{x'^3}{2.3}\right].$$

Add this to (11_1)

$$\therefore \text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'^2 x}{2} - \frac{x'^3}{2.3}\right] - \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (12_1)$$

In (9_2) let $x = -l$ then $y = 0$

$$\therefore \text{EI}t_0 l = \frac{\text{V}_2 l^3}{3} \quad . \quad . \quad (13_2)$$

In (12_1) let $x = l$ then $y = 0$

$$\therefore -\text{EI}t_0 l = \text{P}\left[\frac{lx'^2}{2} - \frac{x'^3}{2.3}\right] - \frac{\text{V}_1 l^3}{3} \quad (14_1)$$

Add (13_2) and (14_1), then transpose, etc.,

$$\therefore 2l^3(\text{V}_1 - \text{V}_2) = \text{P}(3lx'^2 - x'^3) \quad . \quad (15)$$

Had A, O and B not been on the same horizontal line on making $x = 0$ we should have introduced proper values of y.

In eqs. (3_2) and (4_2) let $x = 0$

$$\therefore \text{M}_0 = \text{P}x' - \text{V}_1 l$$

and $$\text{M}_0 = \text{V}_2 l$$

$$\therefore 2l^3(\text{V}_1 + \text{V}_2) = 2\text{P}l^2 x' \quad . \quad . \quad (16)$$

From eqs. (15) and (16)

$$\therefore \text{V}_1 = \frac{\text{P}x'}{4l^3}[2l^3 + 3lx' - x'^2] \quad . \quad . \quad (17)$$

$$\text{and } \text{V}_2 = \frac{\text{P}x'}{4l^3}[2l^3 - 3lx' + x'^2] \quad . \quad . \quad (18)$$

$$\text{V}_1 + \text{V}_2 + \text{V}_3 = \text{P} \quad \therefore \text{V}_3 = \text{P} - (\text{V}_1 + \text{V}_2)$$

$$\therefore \text{from (16)}, \text{V}_3 = \text{P}\,\frac{(l - x')}{l} \quad . \quad . \quad (19)$$

To find the point of contraflexure C, from (3_2)

Put $\text{M}_c = \text{P}(x' - x_c) - \text{V}_1(l - x_c) = 0$.

Substitute in this the value of V_1 from (17)

$$\therefore x_c = \frac{(x'^2 - 3lx' + 2l^2)\,lx'}{x'^3 - 3lx'^2 - 2l^2x' + 4l^3}$$

Cancel the factor $x' - l$

$$\therefore x_c = \frac{(x' - 2l)\,lx'}{x'^2 - 2lx' - 4l^2} \quad . \quad (20_2)$$

$$\therefore x_c < \frac{1}{5}\,l.$$

SUMMARY.

For curve 1.

$$\text{EI}\frac{d^2y}{dx^2} = -\text{V}_1(l - x) \quad . \quad . \quad (a_1)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{P}\frac{x'^2}{2} - \text{V}_1\left[lx - \frac{x^2}{2}\right] \quad . \quad (b_1)$$

$$\text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'^2 x}{2} - \frac{x'^3}{2.3}\right] - \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (c_1)$$

For curve 2.

$$\text{EI}\frac{d^2y}{dx^2} = \text{P}(x' - x) - \text{V}_1(l - x) \quad . \quad (a_2)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{P}\left[x'x - \frac{x^2}{2}\right] - \text{V}_1\left[lx - \frac{x^2}{2}\right] \quad . \quad . \quad . \quad (b_2)$$

$$\text{EI}\,[y - t_0 x] = \text{P}\left[\frac{x'x^2}{2} - \frac{x^3}{2.3}\right] - \text{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (c_2)$$

For curve 3.

$$\text{EI}\frac{d^2y}{dx^2} = \text{V}_3(l + x) \quad . \quad . \quad (a_3)$$

$$\text{EI}\left[\frac{dy}{dx} - t_0\right] = \text{V}_3\left[lx + \frac{x^2}{2}\right] \quad . \quad . \quad (b_3)$$

$$\text{EI}\,[y - t_0 x] = \text{V}_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \quad . \quad (c_3)$$

$$x_c = \frac{(x' - 2l)\,lx'}{x'^2 - 2lx' - 4l^2} \quad . \quad (d_2)$$

If the values of V_1 and V_3 in (17) and (18) be substituted in the eqs. (a), (b) and (c), they then become definite, and we are then able to compute at any point, first, its moment of flexure, by eqs. (a), secondly its angular deflection by eqs. (b) and (14_1), and thirdly from (c) the actual deflections.

Suppose that $t_0 = 0$ (since an extended bearing on the centre pier has a tendency to effect that result).

Then in (c_1) if $x = l$, $y = 0$

$$\therefore \text{V}_1 = \text{P}x'^2\,\frac{(3l - x')}{2l^3} \quad . \quad 21$$

Substitute this V_1 in (a_2), and let $\text{M} = 0$, to find the point of contraflexure

$$\therefore x_c = \frac{x'^2 - 3lx' + 2l^2}{x'^2 - 3lx'^2 + 2l^2}\,lx'.$$

Cancel the factor $x' - l$.

$$\therefore x_c = \frac{(x' - 2l)\,lx'}{x'^2 - 2lx' - 2l^2} \quad . \quad (d'_3)$$

$$\therefore x_c < \frac{1}{3}\,l.$$

The integrations can be performed, and the results reached in the same manner, if the number of the weights be increased, as would be the case in a truss where the dead load is considered to be applied in equal amounts at each joint, and the live load is applied at part of the joints.

II. But for the sake of simplicity, continuing the consideration of the girder, let us investigate the case in which it is loaded uniformly through part of its length.

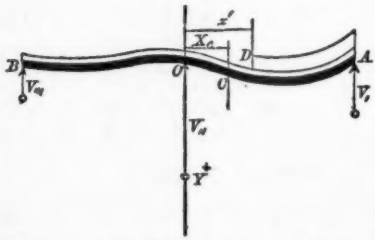
Let q = weight per unit of length of the dead load uniformly distributed along the entire girder,

and p = weight per unit of length of the line load uniformly distributed along part of the girder.

x_1 = the distance of the end of this live load from O.

In a truss, q is the bridge weight per linear unit, which may be taken as about one ton per ft., while p is the weight of a train of engines per linear unit, and may be assumed to be two tons per ft.

FIG. 2.



From the application of eq. (1), to this case, by processes precisely like those previously used, we obtain the following results:

SUMMARY.

For curve 1.

$$\mathrm{E\,I}\,\frac{d^2y}{dx^2} = \frac{1}{2}\,(p+q)\,(l-x)^2 - \mathrm{V}_1(l-x)\,. \quad (h_1)$$

$$\mathrm{E\,I}\left[\frac{dy}{dx} - t_0\right] = \frac{1}{2}\,(p+q)\left[l^2x - lx^2 + \frac{x^3}{3}\right] - \frac{px_1^3}{2.3} - \mathrm{V}_1\left[lx - \frac{x^2}{2}\right] \quad . \quad (k_1)$$

$$\mathrm{E\,I}\,[y - t_0x] = \frac{1}{2}\,(p+q)\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - \frac{px_1^3}{2.3}\left[x - \frac{x_1}{4}\right] - \mathrm{V}_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad (l_1)$$

For curve 2.

$$\mathrm{E\,I}\,\frac{d^2y}{dx^2} = p(l-x_1)\left[\frac{l+x_1}{2} - x\right] + \frac{1}{2}\,q\,(l-x)^2 - \mathrm{V}_1(l-x) \quad . \quad (h_2)$$

$$\mathrm{E\,I}\left[\frac{dy}{dx} - t_0\right] = \frac{p}{2}\left[(l^2 - x_1^2)\,x - (l-x_1)\,x^2\right] + \frac{q}{2}\left[l^2x - lx^2 + \frac{x^3}{3}\right] - \mathrm{V}_1\left[lx + \frac{x^2}{2}\right] \quad . \quad (k^2)$$

$$\mathrm{E\,I}\,[y - t_0x] = \frac{p}{2}\left[(l^2 - x_1^2)\,\frac{x^2}{2} - (l-x_1)\,\frac{x^3}{3}\right] + \frac{q}{2}\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - \mathrm{V}_1\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] . \quad (l_2)$$

For curve 3.

$$\mathrm{E\,I}\,\frac{d^2y}{dx^2} = \frac{q}{2}\,(l+x)^2 - \mathrm{V}_2\,(l+x) \quad . \quad (h_3)$$

$$\mathrm{E\,I}\left[\frac{dy}{dx} - t_0\right] = \frac{q}{2}\left[l^2x + lx^2 + \frac{x^3}{3}\right] - \mathrm{V}_2\left[lx + \frac{x^2}{2}\right] \quad . \quad . \quad (k_3)$$

$$\mathrm{E\,I}\,[y - t_0x] = \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - \mathrm{V}_2\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \quad . \quad . \quad (l_3)$$

To obtain t_0, let $x = l$ in eq. (l_3), then will $y = 0$.

$$\therefore -\mathrm{E\,I}\,t_0\,l = \frac{1}{8}\,(p+q)\,l^4 - \frac{p\,x_1^3}{2.3}\left[l - \frac{x_1}{4}\right] - \mathrm{V}_1\,\frac{l^3}{3} \quad . \quad . \quad . \quad . \quad (l_1)$$

$$\mathrm{V}_1 = \frac{p\,(x_1^4 - 4lx_1^3 - 4l^2x_1^2 + 7l^4) + 6ql^4}{16\,l^3} \quad . \quad (g)$$

$$\mathrm{V}_2 = \frac{p\,(x_1^4 - 4lx_1^3 + 4l^2x_1^2 - l^4) + 6ql^4}{16\,l^3} \quad . \quad (j)$$

$$\mathrm{V}_1 + \mathrm{V}_2 + \mathrm{V}_3 = p\,(l - x_1) + 2ql$$

$$\therefore \mathrm{V}_3 = \frac{p\,(-x_1^4 + 4lx_1^3 - 8l^2x_1 + 5l^4) + 10ql^4}{8\,l^3} \,. \quad (i)$$

Put $(h_1) = 0$, cancel the factor $(l - x)$ and eliminate V_1 by (g)

$$\therefore x_c = \frac{p\,(-x_1^4 + 4lx_1^3 + 4l^2x_1^2 + l^4) + 2ql^4}{8\,(p+q)\,l^3} \quad (e_1)$$

From (e_1) we find the position of C when the live load extends upon the girder sufficiently far to cover C. When the end of the load first reaches to C can be determined by making $x_c = x_1$ in (e_1).

If $x_1 = 0$

$$x_c = \left(\frac{p+2q}{p+q}\right)\frac{l}{8} = \left(1+\frac{q}{p+q}\right)\frac{l}{8}$$

If also

$$p=0 \quad \therefore x_c = \frac{l}{4}$$

$$p=q \quad \therefore x_c = \frac{3l}{16}$$

$$p=2q \quad \therefore x_c = \frac{l}{6}$$

$$p=3q \quad \therefore x_c = \frac{5l}{32}$$

etc., etc.

Similarly put $(h_2)=0$, eliminate V_1 and in case of $q=0$ we can readily find x_c. Then cancel the factor $(l-x_1)$

$$\therefore x_c = \frac{x_1^2 - 2lx_1 - l^2}{x_1^2 - 2lx_1 - 9l^2}l \quad \therefore x_c < \frac{l}{5},$$

which result agrees with (20_2). Also put $(l_1)=0$, cancel the factor $(l=x)$ and eliminate V_2 by (j)

$$\therefore x_c = \frac{p(x_1^4 - 4lx_1^3 + 4l^2x_1^2 - l^4) - 2ql^4}{8ql^3} \quad (e_2)$$

From (e_2) we find the position of C in curve 3 when the live load extends upon the girder from A to any distance towards O.

$$\text{If } x_1 = 0 \quad \therefore x_c = -\left(2+\frac{p}{q}\right)\frac{l}{8}.$$

If also $p=0$ $x_c = -\frac{l}{4}$

" " $p=q$ $x_c = -\frac{3l}{8}$

" " $p=2q$ $x_c = -\frac{l}{2}$

" " $p=3q$ $x_c = -\frac{5l}{8}$

" " $p=4q$ $x_c = -\frac{3l}{4}$

Had the girder been by some means kept horizontal at O, then $t_0=0$ in eqs. (k_1), (k_2), (k_3), (l_1), (l_2) and (l_3), and we should obtain

$$V_1 = \frac{p(x_1^4 - 4lx_1^3 + 3l^4) + 3ql^4}{8l^3} \quad . \quad (g)'$$

$$V_2 = \frac{3ql}{8} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (j)'$$

$$V_3 = \frac{p(-x_1^4 + 4lx_1^3 - 8l^3x_1 + 5l^4) + 10ql^4}{8l^3} \quad (i)'$$

If the load covers C, then put $(h_1)=0$, etc.

$$\therefore x_c = \frac{p(-x_1^4 + 4lx_1^3 + l^4) + ql^4}{4(p+q)l^3} \quad . \quad (e_1)'$$

If $x_1 = 0$, $x_c = \frac{l}{4}$.

Again to find the effect of the live load only, let $q=0$, put $(h_2)=0$, find x_c and cancel the factor $(l-x_1)$

$$\therefore x_c = \frac{x_1^2 - 2lx_1 - l^2}{x_1^2 - 2lx_1 - 5l^2}l \quad \therefore x_c < \frac{l}{3}.$$

If $x_c = x_{12}$, $x_c = (2 \pm \sqrt{3})l = 0.268l$.

III. In case the live load extends from A to some point D *between* O and B of Fig. 2, the eqs. derived from eq. (1) become

SUMMARY.

For curve 1, *i. e.* O A,

$$EI\frac{d^2y}{dx^2} = \frac{1}{2}(p+q)(l-x)^2 - V_1(l-x) \,.\, (m_1)$$

$$EI\left[\frac{dy}{dx} - t_0\right] = \frac{1}{2}(p+q)\left[l^2x - lx^2 + \frac{x^3}{3}\right] - V_1\left[lx - \frac{x^2}{2}\right] \quad . \quad . \quad . \quad (n_1)$$

$$EI\,[y - t_0x] = \frac{1}{2}(p+q)\left[\frac{l^2x^2}{2} - \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - V_1\left[\frac{lx^2}{2} - \frac{x^3}{2.3}\right] \quad . \quad . \quad (o_1)$$

For curve 2, *i. e.*, O D,

$$EI\frac{d^2y}{dx^2} = \frac{p}{2}(x-x_1)^2 + \frac{q}{2}(l+x)^2 - V_2(l+x) \quad . \quad . \quad (m_2)$$

$$EI\left[\frac{dy}{dx} - t_0\right] = \frac{p}{2}\left[\frac{x^3}{3} - x_1x + x_1^2x\right] + \frac{q}{2}\left[l^2x + lx^2 + \frac{x^3}{3}\right] - V_2\left[lx + \frac{x^2}{2}\right] \,.\, (n_2)$$

$$EI\,[y - t_0x] = \frac{p}{2}\left[\frac{x^4}{3.4} - \frac{x_1x^3}{3} + \frac{x_1^2x^2}{2}\right] + \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - V_2\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \,.\, (o_2)$$

For curve 3, *i. e.*, D B.

$$EI\frac{d^2y}{dx^2} = \frac{q}{2}(l+x)^2 - V_3(l+x) \quad . \quad (m_3)$$

$$EI\left[\frac{dy}{dx} - t_0\right] = \frac{px_1^3}{2.3} + \frac{q}{2}\left[l^2x + lx^2 + \frac{x^3}{3}\right] - V_3\left[lx + \frac{x^2}{2}\right] \quad . \quad . \quad (n_3)$$

$$EI\,[y - t_0x] = \frac{px_1^3}{2.3}\left[x - \frac{x_1}{4}\right] + \frac{q}{2}\left[\frac{l^2x^2}{2} + \frac{lx^3}{3} + \frac{x^4}{3.4}\right] - V_3\left[\frac{lx^2}{2} + \frac{x^3}{2.3}\right] \,.\, (o_3)$$

To obtain t_0, let $x=l$ in eq. (o_1). then $y=0$.

$$\therefore EI\,t_0\,l = \frac{1}{8}(p+q)l_4 - V_1\frac{l^3}{3} \quad . \quad (n_1)'.$$

$$\therefore\ V_1 = \frac{p(-x_1^4 - 4lx_1^3 - 4l^2x_1^2 + 7l^4) + 6ql^4}{16l^3}$$

$$V_3 = \frac{p(-x_1^4 - 4lx_1^3 + 4l^2x_1^2 - l^4) + 6ql^4}{16l^3}$$

$$V_2 = \frac{p(x_1^4 + 4lx_1^3 - 8l^2x_1 + 5l^4) + 10ql^4}{8l^3}.$$

From (m_1)

$$x_c = \frac{p(x_1^4 + 4lx_1^3 + 4l^2x_1^2 + l^4) + 2ql^4}{8(p+q)l^3} \qquad (f_1)$$

From (m_3)

$$x_c = \frac{p(-x_1^4 - 4lx_1^3 + 4l^2x_1^2 - l^4) - 2ql^4}{8ql^3} \qquad (f_3)$$

If $x_1 = 0$ $\qquad x_c = -\left(2 + \frac{p}{q}\right)\frac{l}{8}$,

which measures the greatest excursion of the point C from O; compare (e_3). C must never be within $\frac{1}{4}l$ of the end B, lest some sudden impact of the moving load lift that end from the piers.

IV. Let us now consider the case of a truss whose chords are proportioned to the strain brought to bear upon them when the live load extends its entire length, *i. e.*,

$$L_x \propto M_x \text{ and } t_0 = 0.$$

For curve 2, if c is some constant,

$$\therefore\ \frac{d^2y}{dx^2} = \frac{M_x}{EI_x} = c \quad . \quad . \qquad (r_2)$$

$$\frac{dy}{dx} = cx \quad . \quad . \quad . \quad . \qquad (s_2)$$

$$y = \frac{cx^2}{2} \quad . \quad . \quad . \quad . \qquad (t_2)$$

For curve 1.

$$\frac{d^2y}{dx^2} = -\frac{M_x}{EI_x} = -c \quad . \qquad (r_1)$$

$$\frac{dy}{dx} = -cx + 2cx_c \quad . \quad . \qquad (s_1)$$

$$y = 2cx_cx - \frac{cx^2}{2} - cx_c^2 \quad . \qquad (t_1)$$

If $x = l$ then $y = 0$.

$$\therefore\ x_c - 2lx_c = -\frac{l^2}{2}$$

$$\therefore\ x_c = \left(1 \pm \frac{1}{2}\sqrt{2}\right)l = 0.293\,l.$$

Eqs. (t_1) and (t_2) represent parabolas having a common tangent at C. It is evident that if the chords were exactly proportioned to the strain they are subjected to, the curvature would at each point be uniform, *i. e.*, the curves would be arcs of equal circles, and in case the depression is small $x_c = \frac{1}{3}l$ nearly.

The results of these investigations may be stated thus:

1*st.* A drawbridge of two equal spans when uniformly loaded never has its points of contraflexure at a distance greater than $\frac{1}{3}l$ from its centre, provided the piers are at the same level, and the drawbridge straight.

The conditions of this proviso are readily fulfilled in this way, viz.: the bearings on the end piers may be raised or lowered to such an extent as to cause the truss to exert on these bearings the computed pressure obtained from (g) and (j) when $p = o$.

The mutual relation of x_c and V_1 when $p = 0$ may be shown thus by the principle of the lever.

If	$x_c = l$	then	$V_1 = 0$,
"	$x_c = \frac{9l}{12}$	"	$V_1 = \frac{3ql}{24}$,
"	$x_c = \frac{8l}{12}$	"	$V_1 = \frac{4ql}{24}$,
"	$x_c = \frac{6l}{12}$	"	$V_1 = \frac{6ql}{24}$,
"	$x_c = \frac{4l}{12}$	"	$V_1 = \frac{8ql}{24}$,
"	$x_c = \frac{3l}{12}$	"	$V_1 = \frac{9ql}{24}$,
"	$x_c = \frac{2l}{12}$	"	$V_1 = \frac{10ql}{24}$,
	etc.,	etc.,	etc.

2*d.* A truss so supported never, under any distribution of a partial uniform load, has a point of contraflexure at a distance greater than $\frac{2}{3}l$ from its centre.

3*d.* If the draw is swung from its end piers, the entire upper chord undergoes tension, the lower compression, and the moment of flexure at O is

$$M_0 = \frac{ql^2}{2}.$$

When the draw is supported on three piers and loaded throughout, the moment at O is as large as is possible under a load, and is, if we take $x_c = \frac{1}{3}l$,

$$M'_0 = \frac{1}{3}(p+q)l \cdot \frac{l}{3} + \frac{1}{2}(p+q)l \cdot \frac{l}{6}$$

$$\therefore\ M'_0 = \frac{1}{6}(p+q)l^2.$$

Now if

$$p = 2q \qquad M'_0 = \frac{ql^2}{6}.$$

Hence if the truss is of sufficient strength to swing, the centre third of it is sufficiently strong to sustain a uniform live load of twice the weight of the truss.

4th. The point of contraflexure may approach the centre O, so that $x_c = \frac{1}{6}\,l$.

RECENT IMPROVEMENTS IN STEAM BOILERS.*

From the "English Mechanic and World of Science."

When I read a paper before this Society two years ago I endeavored to give the members present on that occasion an account of a cast-iron boiler, which had been brought out originally in the United States, and subsequently introduced to a considerable extent in this country. One of the advantages of this boiler over those of the Cornish and Lancashire type is, as I pointed out, a rapid circulation of the water. To obtain this essential feature of improved steam production has been a chief object in all the recent improvements in steam-generation I have to describe to you this evening. By recent, I may here state, I mean within the last ten or twelve years.

As you are aware, the Cornish boiler is a long cylinder laid on its side, and is constructed with an internal cylindrical flue running all the length of the boiler, and fixed eccentrically to the outer shell. This flue contains the fire-grate, and is entirely surrounded by water. As the flame of the furnace and the heated gases have not yielded up nearly all their caloric on reaching the back end of this internal flue, other flues are formed in the brickwork setting of the boiler. The fire itself is within the boiler, and the heat is brought into further contact with the water to be raised into steam, by the products of combustion being led along the external flues to the chimney. It is evident that a certain portion of the heat thus supplied and conducted through flues, formed to a great extent of brickwork, must be absorbed by that brickwork, and, from the fact of the flues being external, only a portion of the heat passing along them can be effective in raising the water into steam. From the nature and arrangement of this type of boiler slow combustion is the only means by which it can be worked economically. The heat could not be absorbed by the water with sufficient rapidity to render quick combustion economical; because, in addition to the increased caloric which would be thus absorbed by the brickwork of the flues, there is a large inert mass of water to be raised into steam. That a fair percentage of the heat may be utilized sufficient time must be allowed, otherwise a certain proportion of heat must pass off by the chimney, as the circulation of the water is sluggish. If, however, means are devised by which the water to be raised into steam can be brought more quickly into contact with the fire and products therefrom, a more rapid combustion can be employed with at least equal economy. If, again, an equal quantity of steam can be raised in the same time by a much smaller boiler, and at—say—even the same expenditure of fuel, here is a decided gain.

To effect this, the large body of inert water, in boilers on the Cornish system, must be broken up and separated, in order that the heat may be brought, as it were, into more immediate and intimate contact with the water in smaller bodies. In doing this, care should be taken that sufficient oxygen be supplied for the support of the combustion, and, thereby, for the addition of intensity to the heat. This is the direction in which all the more recent improvements in boilers, that I know of, tend. It is important, besides, that the circulation of the water in a boiler should be in exact proportion to the heat supplied.

The first boiler I have to bring before you this evening is the "Field Boiler." In this arrangement, the heat being led by many small channels through the water, the water itself is thereby caused to pass in small streams through the hottest part of the furnace, and at a rate proportionate to the heat supplied, as the one effect is the complement of the other. Therefore, as the heat is increased or diminished, so will the speed of the circulation of the water be more or less rapid, and no waste of caloric

* A paper read before the Civil and Mechanical Engineers' Society, by W. Forsyth Black.

will arise from quick combustion. This boiler consists of two principal parts, viz., the space for water and steam, and the furnace where the combustion is carried on.

For stationary engines it is made of a cylindrical form, set on end. An inner cylinder contains the furnace and the circulating tubes, and from the top centre of this the uptake leading to the chimney springs. The water surrounds this inner cylinder, and rises to a level above the tubes, and surrounds the lower part of the uptake. The tubes themselves are disposed annularly round a central flue, which leads straight up to the uptake, and to insure that, instead of directly ascending the same, the flame shall spread out round the tubes, a damper, or baffle of cast iron is suspended in this said flue, and can be raised or lowered at pleasure, for in some measure regulating the draught. The tubes, wherein most of the peculiarity of this boiler consists, are closed at the lower ends, and within each is freely suspended, by means of feathers, a smaller tube, open at both ends. The outer tubes are fixed to the tube-plate, which is the crown of the internal cylinder of the boiler above mentioned, as follows:—The holes in the tube-plate, for receiving these tubes, are made slightly conical, their smallest diameter at the lower surface of the tube-plate being equal to that of tubes externally, and taper upwards. The upper ends of the tubes having been slightly expanded, a tube is placed in position; a conical steel mandrel is then inserted in the upper end of the tube, and one or two blows of a hammer are struck on this mandrel to further extend the tube, and to insure it being jammed into the hole in the tube plate. From the modus operandi it is evident that a new tube can at any time be readily fitted should one be injured, and that no specially skilled workman is required for this purpose. The outer tubes are of wrought iron, and are from 2 to 3 in. outside diameter, and from one-eighth to three-sixteenths of an inch in thickness. The inner tubes are of brass, from one-twelfth to one-sixteenth of an inch in thickness, and the annular space between these and the outer tubes half an inch across, which fixes diameter of these inner tubes. These have at their upper ends feathers of brass brazed on to them, by which means they are suspended in the outer tubes. These upper ends are further furnished with funnel-shaped mouths brazed on to them, which serve as deflectors to guide and accelerate the circulation of the water. The tubes are placed sufficiently far apart to allow the heat free access round them, and the distance between is usually not less than half a diameter of outer tubes.

When the fire has been lighted, and the heat commences to rise up round the tubes, the water in these begins to circulate. As an increment of heat is added to the water in the annular space between the outer and inner tubes, the water therein begins to ascend, and its place is supplied by cold water flowing down the inner tubes. This action goes on increasing gradually till boiling-point of the whole water is reached, when the velocity of flow is greatly increased, owing to the great difference in specific gravity of the water, mixed with steam, ascending from immediate contact with the hottest part of the fire, and of the solid water descending from above.

In the case of a boiler having 490 sq. ft. of tube surface, we have the outer tubes 2 in. in internal, and 2¼ in. in external diameter, and the inner tubes 1 in. in external diameter, leaving an annular space of half an inch all round between the tubes. Taking the flow of water down the inner tubes at 10 ft. per second, the number of tubes at 289 will give a quantity of water equal to about 80 gallons passing down the tubes, and being brought under the most intense action of the furnace. Owing to the circulation, the water passing down is from the part of the boiler where the water is less heated, and will be the more ready to absorb the heat of the fire as it approaches the hottest part of the furnace. It passes on carrying with it to the top part of the boiler its steam, which remains in the steam chest there till used by the engine, and the feed water coming up from the point of injection near bottom of boiler, passes up through the annular space, between the outer and inner cylinders of the boiler, and down through the inner tubes to the hottest point, and so the circulation goes on.

An important point to be considered with regard to boilers is incrustation; how far it goes on, and how far it is avoided. It is clear that where the circulation is rapid, as in this and kindred tubular boilers, no deposit can settle in the tubes; but must fall to bottom of boiler. From thence it is expelled periodically by the blow-off cock, and

when the boiler is not at work, by means of the mud-hole it can be thoroughly cleared away.

The simplest form of this boiler, viz., the upright and cylindrical, is that employed for stationary engines. Two boilers of this description occupying a ground space of less than 90 sq. ft. have been found to do the work of two Cornish boilers covering an area of about 400 sq. ft. A boiler of this same design calculated to evaporate 25 cubic feet per hour, and nominally of 25 horse-power, was erected some years ago at a colliery in the north of England, and drove an engine having a sixteen-inch cylinder and a three-feet stroke at the rate of 50 revolutions per minute, under a pressure of 50 lbs. of steam per sq. in. This was the average performance, and from a record kept, it was found that the maximum evaporation was 26 cubic feet, and the minimum 22.6 cubic feet. The indicated horse-power of the engine was 55. The amount of coal used during 114 hours was 167 cwt., equalling 164 lbs. per hour, or very nearly 3 lbs. for each indicated horse-power. The fuel used was refuse coal from the colliery which could not be sold, and refuse from the coke ovens. In experiments made with five 60 horse-power boilers of this kind, used to work hydraulic machinery for warehousing grain, steam was got up from cold water to a pressure of 10 lbs. in 20 minutes; while in the case of Cornish boilers three-quarters of an hour would have been necessary to attain a like result. In 30 minutes there was steam of 50 lbs. pressure. Turf has also been used for fuel in boilers of this style, and with satisfactory results, owing to their excellent draught.

This boiler has also been slightly modified, and employed for utilizing the waste heat from re-heating furnaces.

To admit of a fuller advantage being taken of the hottest part of the flame by bringing it more directly on the tubes, a down draught modification has been made by Mr. Field in conjunction with Mr. Lloyd Wise. This consists in placing the chimney at the side of, and at a little way away from the boiler, and in filling up with additional tubes the central flue of the arrangement I have described. Inside the fire-box, at a little distance from the cylindrical wall of it, and opposite the furnace door, is fixed a cast-iron diaphragm, which is protected from the heat of the flames by a lining of fire-clay. This diaphragm extends to within a suitable distance of the tube plates, and the smoke and gases pass over it, through the space left, then down between it and wall of inner cylinder, and onwards by flue in brickwork setting of boiler to the chimney. The top of this boiler is flat, and is stayed to the tube plate.

Boilers of this arrangement have given satisfactory results. One has been for some time in constant use at the Victoria Works, Coal Yard, London. There repeated competitive trials have been made between this and a Cornish boiler. The latter is covered in with brickwork, is well set, and has a good draught. It was clean, and consumed 4 tons of coals, at 20 shillings per ton, in 16½ hours, which gives eightpence halfpenny per hour; whereas the former boiler, in 60 hours, consumed 2 chaldrons of coke at 16 shillings per chaldron, which gives fivepence halfpenny per hour, or a saving of over 30 per cent. Both boilers performed exactly the same work during their respective trials. Field tubes have also been fixed to Cornish, and in double-flued boilers, and have been the means of a great saving of fuel. Beginning a short distance from the bridge, the tubes are fixed in the method already explained by drifting, and are arranged, in 2 or 3 rows, according to size of boiler, continuously to the front end of the boiler. This is accomplished from the inside of the boiler, and, consequently, nothing has to be disturbed. In addition to the fuel being economized, an increase of steaming power is acquired. It has been found from practice that not only are the tubes themselves free from scale, but also that no sediment lodges on the plates into which the tubes are fixed, whereas previous to this addition a thick layer of scale accumulated on this part of the boiler. This is due to the activity of the circulation of the water. To test comparatively the effect of such an application of tubes to Cornish boilers, a thorough trial was made for a considerable time, as regards both evaporation of water and economy of fuel. Both boilers (*i. e.*, the one furnished with tubes, and the other an ordinary Cornish boiler) were exactly of the same size, had one chimney, and were worked under conditions precisely similar. The size of each boiler was 25 ft. 6 in. long, and 6 ft. in diameter, and each had an internal flue 3 ft. in diameter. One was furnished with 36 tubes, which was only about one-quarter of the

number that might have been employed with advantage. The result was fully 12 per cent. of a saving of fuel in favor of the tubed boiler.

The following is the report of an experiment by the engineer of some extensive mills in the north of England, in conducting which a water-meter was used:—

"Boiler 28 ft. long and 6 ft. diameter, having two flues 2 ft. diameter, half-inch plates, fire-grate 2 ft. wide and 4 ft. long; coal burned, 1 ton 18 cwt = 4,256 lbs.; water evaporated, 2,225 gallons=22,250 lbs., which gives 5.23 lbs. water evaporated per 1 lb. of coal."

"Boiler 28 ft. long and 7 ft. diameter, having two flues 2 ft. 9 in. diameter, half-inch plates, fitted with 45 'Field tubes' 12 in. long in each flue. Coal burned, 3 tons 12 cwt. = 8,064 lbs.; water evaporated, 6,287 gallons = 62,870 lbs., which gives 7.8 lbs. of water evaporated per 1 lb. of coal."

This gentleman adds: "Very bad coals were used throughout; but the experiment shows a great advantage in the use of Field tubes."

These boilers, upright and cylindrical in form, have been employed for steam launches, and boilers of this type, and of this or other internal arrangements, commend themselves very obviously for such service on account of the great saving of space, which in this case is specially of much moment. Two boilers of the same type were fitted to a fine lake steamer, the Schwyze, launched on Lake Constance by a Swiss firm of engineers. The boat is 130 ft. long, 16 ft. beam, and draws 2 ft. 8 in. of water. She is fitted with a pair of inclined direct-acting condensing engines, 17 in. cylinder, 2 ft. 8 in. stroke. The steam is worked expansively, being cut off at one-tenth of the stroke. Her boilers are 4 ft. 10 in. in diameter, and expose 600 ft. of heating surface. With steam at 60 lbs. pressure 150 indicated horse-power is obtained from the engines with 140 kilogrammes=310 lbs. of Saarbrück coal per hour, and with this the speed of the boat is equal to 12 statute miles per hour. This is the average speed; but considerably higher results have been obtained by forcing the fires. The height of the boilers is limited below what would have been desirable, in consequence of the shallow draught of the boat, and from the fact that she has to pass under the bridge at Constance, and on this account the economy of fuel is not greater.

On the Continent, and more especially in Germany, the "Field" system is extensively used, and lately, I understand, Mr. Krupp, of Essen, was applying for quotations for boilers on this plan, of a collective power of 1,000 horses, several of which were to be individually of 100 horse-power.

Mr. Alexander Chaplin's arrangement of tubular vertical boilers is his improvement in this direction on the vertical dome boiler of the simplest form, which he introduced ten years previous to what I am now about to describe. I may mention in passing, that this consisted of an outer and inner cylinder, with the addition for larger sizes, from 13 horse-power upwards, of 1 or 2 cross tubes in upper part of internal cylinder, which forms the fire-box. On the top of this, which is of a dome shape, sediment cannot lodge; but falls into the water space below the level of the fire-grate, from which it is easily removed by the blow-off cock at regular intervals, according to the quality of the water used for feed, and by taking off the mud hole door when boiler is not at work. The crown of fire-box is so far removed from the fire-grate that it is not liable to be acted on injuriously by the heat. Between outer and inner cylinder there is an annular cooler space surrounding the fire-box, above the top of which there is ample water, and especially steam space. The uptake which leads from furnace crown to funnel, or chimney, at top of the boiler is tapered to increase the draught, and serves, in addition, the purpose of a very efficient and strong stay. The large area of the fire-grate, with the high fire-box, serves to burn up the cheaper kinds of fuel; coal dross, wood, peat, refuse of sugar cane, and such cheap and refractory fuel, by the addition of a forced combustion and smoke-burning apparatus, can be profitably employed.

The cross tubes I have mentioned above are from 6 to 12 in. in diameter, and are placed across upper part of the fire-box, at an angle, to prevent sediment lodging within them. When two are employed, they are placed at right angles, and one above the other.

By the addition of hanging tubes to his simple dome and internal fire-box boiler I have just described, and by so superseding the employment of cross tubes for larger

sizes, Mr. Chaplin has produced his tubular boiler, which he introduced in 1865. The tubes, which are closed at their lower ends, descend from the crown of the fire-box, which thus forms the tube-plate. The tubes are screwed at their upper ends, and secured in the tube-plate, in which holes, furnished with screw threads, are made to receive the tubes. The section of the tube-plate is curved, and as the holes for the tubes are bored at right angles to direction of curve, the tubes when placed in position converge towards each other at their lower ends, which nearly approximate.

As in the former case, the uptake flue leading straight to the chimney, stretches upward from the centre of dome of fire-box, and is tapered, its lower end being the narrowest part. The object in making the tubes thus converge, is to insure that the flames and heated gases shall not pass directly up the chimney, but be drawn to the sides of the fire-box in the first instance, and then across the tube to the uptake. As in the other case, the large fire-box and good draught admit of refuse, refractory coal, and fuel being burnt, and, when necessary, combustion may be assisted by such means as I have indicated. The tubes are from 2 to 3 in. in diameter; the metal is from one-eighth to three-sixteenths of an inch in thickness. As a minimum they have been fixed with the ends only 9 in. from fire-grate.

This arrangement of boiler has been used extensively for steam cranes, stationary, portable, and contractors' locomotive engines, as well as for high-pressure boat engines, and the boilers are generally worked at a pressure of 60 lbs. on the sq. in.

More recently—viz., in 1870—the same inventor introduced a system of separation applicable to all the forms of tubular boilers he has employed, as well as to others of a kindred description. In many cases, by facilitating transport, this is an improvement of much practical value. These separating boilers, then, are in two parts. The one contains the steam and top water space, and in the case of the tubular arrangement carries, in addition, the tubes.

The other contains the fire-box, and the annular water space surrounding it. For a reason that will presently appear, the upper portion is of a greater diameter than the lower. There is no difficulty about the junction of the two parts, as with a slight exception the joint at their connection is simply a smoke joint. The bottom of upper portion is also both tube plate and fire-box crown. Communication between the steam and water space in upper portion, and the annular water space surrounding fire-box in lower portion, is effected partly by means of tubular studs or bolts. If the former, these are screwed into top of annular space (which is made close at top), and, projecting through holes in bottom of upper portion, are then secured by nuts which must be screwed down in such a way that no steam will pass into smoke joint. This latter is kept tight by a joint ring of sheet lead. This by melting would allow the steam to escape, and so give warning should the water in the boiler sink too low from any neglect or other extraordinary cause.

Additional communication between the two parts of this style of boiler is obtained by outside circulating pipes, which depend vertically from the bottom and projecting part of upper portion to the lowest part of the boiler. These can also be used for removing any sediment that may lodge on outer circle of the tube plate, which in this boiler is rather beyond the action of the circulation of the tubes. The cocks at lower end of these outside pipes are so arranged that, in addition to establishing, as desired, the communications necessary for these operations, they can be used for blowing down the boiler, and for expelling the sediment which will lodge at lowest part of annular water space. Through one of these cocks also the feed water may be supplied. If a central flue be employed instead of converging tubes, it is necessary, as in former boiler, to make use of a damper or baffle, which should be arranged so that it can be raised or lowered as may be desired.

When a boiler of this kind is to be put to work, the communication by outside pipes between upper and lower water spaces is shut off by means of the cocks, and when steam begins to rise, by turning these cocks in the direction proper for that object, the said communication is established, and increased circulation results.

On account of bad health, and business engagements, the inventor has not had leisure to fully introduce this improvement; but he found that in the only boiler of this kind that had been made, and which was constructed from his own design, all his

expectations were realized. This boiler was made for a river steamer.

Mr. Chaplin has had a long and extensive experience in the construction of boilers, and when the idea of making use of hanging tubes first occurred to him, he tested the operation he expected would be carried on in these tubes in the following manner:—

A small tank open at the top was made, and a tube, closed at lower end, was screwed into the bottom of this tank, and depended vertically. The tube and part of the tank were filled with water, and this experimental and fragmentary boiler was placed on a smithy fire, which was made to burn fiercely by means of the blast. Every 10 or 11 seconds a ball of steam as it were seemed to rise up to surface of the water, which, as it were, divided, to allow the steam to pass off. There was no disturbance upward of the water, and nothing at all approaching to a miniature jet of water appeared above the tube when the steam came up. This satisfied the experimenter that boilers furnished with these tubes would not prime, and that from the intense action of the first tube, no sediment would lodge in such tube, both which convictions actual practice proved subsequently to be correct. The experience of years has also proved that to whatever extent such appliances as internal tubes may assist or increase the circulation of the water, simple close-ended tubes used in these boilers establish an efficient circulation. The water in fact arranges its own currents of circulation under these circumstances. An extensive manufacture of these boilers is carried on at the present time.

The last I have to bring before you this evening is the Davy-Paxman boiler. The inventors set out from the same upright cylindrical type of boiler we have already been considering.

To bring the water into immediate and direct contact with the hottest part of the fire, these gentlemen employ tubes differing in arrangement from both the previous tubular boilers I have been endeavoring to describe to you. As in those, the tubes here, too, depend from the tube plate into holes in which their upper ends are fixed; but when they approach to within 10 or 12 ft. of the fire-grate they are bent round, and their lower ends are fixed in holes in the cylindrical wall of the fire-box. The tubes are also tapered from commencement of bend to their lower ends. The entire arrangement is shown in engraving.

There is a strong upward rush of water through the tubes, owing to the action of the fire on them when the boiler is set to work. The inventors further increase, by tapering the tubes as described, the velocity of this rush, so no sediment will be deposited elsewhere than in the bottom of the boiler, whence it is removed by blow-off cocks when the boiler is at work, or when not, through mud-holes, by taking off the mud-hole door. The tubes are kept tight by being expanded when placed in position, and "snapped." Should a new tube be required the old one is cut out; the new one is first inserted in the tube plate, through which it is projected; the lower end is then inserted in its place, and driven tight from top end. From the confined size of annular space, it is impossible to expand and snap it; so it is caulked, which is found sufficient. The top end can be easily got at for fixing by ordinary method. The makers have put in hundreds of tubes in this way, and have never heard of one failure of any so put in.

The inventors found so rapid circulation, or so violent action took place in their boiler, that, in order to prevent the serious evil of priming, they were obliged to employ a special arrangement somewhat similar in purpose to the funnel-shaped deflectors of the Field boiler. This consists of a conical valve, furnished with a flat dished cover, fixed a little above it, and this kind of deflector is inserted in top end of each tube, as shown in engraving.

When this deflector was not used, it was found that the water rushed up like a fountain from the tubes, and this fact was seen by the manhole being left without its door, and by heat only sufficient to raise the water to boiling-point being supplied. In same manner when the deflector was applied, it was seen that the rush was changed into a horizontal and downward movement of the water, the result of the cover of deflector valve intercepting the upward force of the water. The surface on water level was thus left smooth, and the danger of priming averted.

The deflectors are simply driven in tight by hammering until about a quarter of an inch of space is left between their covers and the tube plate. In the central flue there is suspended a damper, or baffle of cast iron to prevent, as in the previous

cases, the too ready escape of the heated gases by the chimney. This is adjustable as to its height above the fire-grate, and can be raised or lowered by hand. These tubes, I am informed, have been applied many times to Cornish boilers, and the results are said to be a saving in fuel of from 25 to 40 per cent.

As in all boilers of this type, steam is raised very quickly in the kind we are now considering, and 60 lbs. pressure has been raised from cold water in 20 min., and the same has even been done in 17½ min.

In Messrs. Davy, Paxman & Co's factory a good Cornish boiler was replaced by one of these, and the experience of these gentlemen is that steam can be raised to 50 lbs. or 60 lbs. in 15 min., and that the amount of coal used for a day of 10 hours is very litle more than was consumed by the Cornish boiler during the morning, and that, in addition, twenty-five per cent. more work is done.

A 10 horse-power boiler was used at the International Exhibition for driving the machinery in the Scientific department, and in 13 working days the consumption of fuel was 26 cwt. of coke, and the duty done by the engine was 6 horse-power, thus making the low daily consumption of 2 cwt. of coke.

With regard to the style of tubes here employed Mr. Chaplin made use of a similar contrivance many years ago; but he kept them higher above the fire-grate at their lower ends, by which means he avoided the excessive action which here necessitates the use of deflectors. When the tubes are brought down so low as shown in the engraving, vaporization takes place low down in the tube, and the steam in its upward rush carries the water along with it from upper part of the tube. The reason Mr. Chaplin did not go on making boilers with this kind of tube was simply because he found them too expensive.

How far the various boilers will compare in price I cannot definitely say; but from the simplicity of construction, I should place Mr. Chaplin's first as to that advantage.

As regards steam raising, I should say all are about on a par; but unless some special trial were instituted as a comparative test, one can only pronounce on this point by reasoning from analogy.

All these boilers possess their essential principles in common, and all are arranged for the rapid and regulated circulation of water, its intimate contact in small bodies with the heat of the furnace, an economical employment of the same, and for the fall and deposit of sediment at the bottom of the boiler. The results from these most important features are a rapid production of steam at a small expense of fuel, and an absence of scale or deposit upon those parts of the boiler to which the heat is applied.

I have only to add that, from their construction, these boilers are not nearly so liable to explosions as are those of the Cornish and kindred types.

REPORTS OF ENGINEERS' SOCIETIES.

CIVIL AND MECHANICAL ENGINEERS' SOCIETY.—Mr. C. H. DRIVER, F. R. I. B. A., read a paper on "Engineering—its Effect upon Art."

He divided his paper into three portions, the first being his definition of art; the second as to what was enginering; and the third being the effect of each upon the other. Art (he said) was as old as man; it was universal; and was essentially human. Engineering, as well as art, could be traced to the earliest period of the world's history; but there was this difference between art and engineering, the former was human and the latter was not. Engineering might be taken to mean the art or science of construction. Art and engineering had been at all times coexistent, and while art was dependent upon engineering, the contrary was not the case. One great and good effect of engineering upon art was shown in printing, where, by the multiplicity of the works of poets, philosophers, and others, the knowledge of their contents was extended far and wide amongst all classes. By a multiplicity of artistic objects considerable benefit accrued to art, artists, and to the art-loving public. There were evils to art which might be caused by engineering; but whatever they were, it was the result of misapplication of engineering. When it ceased to be truthful, when it endeavored to make one material represent another, then it was creating a sham, and was prejudicial to art. He did not wish to place engineering above art, for in the relative position of one to the other, art was superior to engineering, which should be the servant of art and not its master; it should be a useful workman while art supplied the master mind. In the carrying out of works, his idea was that the architect and engineer should be joined in one; and he urged that the young engineer should become more familiar with architecture than was his wont.

THE MANCHESTER SCIENTIFIC AND MECHANICAL SOCIETY.—A paper on street tramways and cars, was read by Mr. G. B. Jerram, and the following were recommended as essential qualifications for street tramways:

1. To have as narrow a width of rail as possible.

2. That the groove in the rail should be as small as possible, and of such a shape as to hold little dirt, in which it would be almost impossible for any hard substance to become fixed.

3. That the rails should be laid in such a manner as to be perfectly even with the adjoining pavement or surface of the road, so as not to offer any inequalities of surface.

4. That all points and crossings should be firmly set, so as not to get out of gauge with any lateral strain.

5. To be of such construction as to be lasting and capable of easy repair without much disturbance to the streets.

There were two methods of construction, one being iron lines with wooden bearers, and the other roads consisting entirely of iron. One of the systems which he noticed had been recently patented by Mr. J. H. Lynde, of Manchester. It consisted of a flat-bottomed rail, with side flanges, bedded into Val de Travers asphalt. The process of construction was as follows:—Only so much of the paving sets was removed as would be intersected by the iron rail, and a width of 3 in. preserved on each side. The whole space was then filled with concrete to within 2½ in. of the level of the rail. In twenty-four hours this would be sufficiently set to receive the liquid asphalt in which the rail was set. The surface of the asphalt was grooved in a line with the sets of the road. By this system a very small width of rail was needed; in fact, only enough for the wheel of the car to move on, and enough to protect the groove. It seemed that asphalt made in a certain manner had a very great tenacity for iron, and it was thought that the hold it had would be sufficient to keep the rails in place. As a test of this, two lineal yards of tramway, according to this plan, had been laid in Manchester, and up to the present time there was no appreciable wear and tear.

IRON AND STEEL NOTES.

Iron Pig Rich in Silicon.—Silicium, which was once regarded as an impurity in cast iron, has taken rank at last as one of the indispensable elements in cast iron destined for conversion into steel by the Bessemer process. The silicium, by combustion in the converter, develops three times more heat than the same weight of carbon, by being transformed into carbonic oxide, at least so affirms a communication to the "Academie de Sciences."

These ores, rich in silicium, effect thus a remarkable saving in fuel, and can be maintained during conversion for a great length of time at a much more elevated temperature than ordinary ores, producing a more excellent conversion into steel.

A. M. H. Sainte-Claire-Deville employs a special method with excellent results, thus:—The silicious pig is brought to a condition of fusion in a crucible of quick-lime, upon a hollow spindle fed by a stream of ordinary coal and oxygen gas. This forms a bath, which oxidizes quietly in the presence of a considerable excess of oxygen. The metal, maintained constantly in motion by the current of gas, forms continually a colored skin, which gathers round the edges of the bath, and is constantly renewed, as in the cupellation of silver. Without altering the speed of conversion, the heat may be raised much beyond fusion point. These phenomena distinguish completely the conversion of ores rich in silicium from ordinary ores, which, reduced under the same conditions, do not produce the bright and colored streaks. The production of the streaks is due to the dissolution of the hydrogen and of the oxide of carbon in the bath. Again, whilst ordinary ores dissolve a great quantity of these gases, the silicious ores dissolve but traces. MM. Troost and P. Hautefeuille have made some interesting experiments upon the production of artificial silicious pig-iron where required.

These experiments show that, at a temperature above that of fusion of cast iron, the carbon of the iron freely reduces silica, the carbon exhanging places with the silicium. And on the other hand, it results that where it is wished to avoid the introduction of silicium into cast iron or steel it should be reduced in vessels of lime or of magnesium. These conclusions appear to be confirmed by the observations of Mr. S. Jordan, who says that to obtain pigs very rich in silicium, it is necessary that the operation in the furnace should be very hot and very slow; the reduction of the silica in the presence of the carbon and of the iron has, under these conditions, the time to take place effectually. It is necessary that the fettling should be very silicious and very aluminous.

In spite of this, it must not be forgotten that other causes may intervene to prevent the production of silicious pigs. The reaction of the carbon of the iron upon the silica is slow, and again, the basic nature of the slags is very little favorable to it. It has, moreover, been established that a silicious pig, melted in lime or in a silicate of lime, loses its silicium. One of the causes of the production of silicious pigs is to be found in the action of the silicates of the alkaline metals, which exist always to a sensible degree in the hearths and fluxes.

The influence of the alkaline metals is easy to prove: heat in a wind furnace a mixture of carbonate of potash, charcoal, iron filings, and silica; this mixture brought to a high temperature gives a metal containing 15 or 16 per cent. of silicium and 2.9 of carbon. This reaction, much more rapid than the former, produces a silicious metal during its rapid descent through the hottest zone of the blast-furnace.—*Iron.*

RAILWAY NOTES.

Peachbottom Narrow Gauge R. R.—On Friday, March 27th, the President and Directors of this road passed over the first 12 miles of its track laid down. The train which carried them was also the first which ever went over the track. They expressed themselves as highly pleased with the condition of the road-bed, and the working of the equipment.

This road is a three-foot gauge, starting from Oxford, Chester county, and running westerly until it crosses the Susquehanna at Peachbottom; from there it runs to York. With the exception of a few miles, the entire road from Oxford to York, 60 miles, is graded, and very shortly tracklaying will begin from York eastward. All this grading has been done by stock subscriptions, and

not a share of stock has been issued except for value received. The Company has no floating debt and has not borrowed. It now proposes to ask a light loan in the shape of an issue of bonds of $12,500 per mile, to complete the line and thoroughly equip it. To secure this it offers to the takers of its bonds a first mortgage on a line which, with its equipment, cost $14,000 per mile, and which runs through three of the richest agricultural counties of Pennsylvania. In addition, it offers the proceeds of a drawback contract with the Philadelphia, Wilmington and Baltimore, and Baltimore Central railways, by which each of these roads allows a rebate on all freight or passenger traffic brought to them or taken further for them by the Peachbottom. This drawback for the first year is 25 per cent.

This narrow gauge road is an interesting fact to Eastern Pennsylvania, large districts of which are eagerly hoping for the development which follows their opening up by a railway, but which dare not even look forward to the expense of undertaking the construction of a broad gauge line. In Pennsylvania these narrow gauge lines may be indefinitely extended, and become the natural feeders of the old trunk lines of broader gauge. The Philadelphia, Wilmington and Baltimore railway in this drawback contract recognizes this, and the harmonious working together of these two roads, which represent systems that in some States are rivals, augurs most happily for the prosperous and thorough development of Pennsylvania.—*Bulletin of the Iron and Steel Association.*

ENGINEERING STRUCTURES.

JARRE'S POWER PUMP.—The hydro-pneumatic pump of M. Jarre, for the transmission of power to a considerable distance, is the subject of a report by M. Haton to the Société d'Encouragement of Paris. The problem of transmitting power over long distances full of obstacles is undoubtedly not an easy one, and M. Jarre avails himself of compressed air for the purpose, and acts directly on the water without the aid of a piston. The pressure in the air conduit being subject to little variation, and resulting from the action of the force-pump, which is placed at a long distance from the source to be drawn from, a special arrangement was necessary to work the valves of injection and emission.

M. Jarre has adopted an intermittent fountain. An oscillating beam alternately opens and closes the way through which the compressed air finds its way to the surface of the water to be raised, according to the variations of weight in two movable parts of the apparatus, when in air and when immersed in water, that is to say, when the level of the water rises or falls. The action of the compressed air thus follows closely the movement of the water, and the pump continues its action so long as the pressure of the air is sufficient.

Several pumps of this kind have worked with success for two years at the Ornans Works, of which M. Jarre is directing engineer. It is admitted that there is a disadvantage in causing the air to act directly on the water, because the effective pressure is thus limited to the fixed pressure of the ascending column of the liquid, and by any loss in the conduits; but this objection is compensated by the special advantages of the pump in certain cases. Thus, one of them is placed at the distance of nearly 500 ft. from the motor, and the compressed air reaches it through a tube only four-fifths of an inch in diameter, and having twenty-eight heads at right angles. The water raised, which amounts to 18 gallons per minute, is conducted through a pipe of 1 and 3-5 in. in diameter, with nine right-angle bends, and two stopcocks.

THE ST. GOTHARD TUNNEL.—The length of this immense work will be 14,900 metres, or 9 miles 715 yards. The altitude of the northern entrace, at Goeschenen, will be 3,700 ft. above the level of the sea and that of the southern entrance, 3,850 ft. The highest point in the interior of the tunnel will be 3,873 ft. above the sea level, which will be reached by a rise from the Goeschenen end of 7 per 1,000; from this point there will be a descent towards Airolo of 1 per 1,000. The rock to be traversed is for the most part mica-gneiss and mica-schist. Great improvements are stated to have been introduced into the perforating machinery employed, but thus far the progress of the works can scarcely be said to have been very rapid. The length of tunnel actually pierced is, however, a little more than 2,330 ft. on each side, and an advance of 10 ft. is daily made in each gallery at Goeschenen; the rock is perfectly solid, requiring neither planking nor arching; but at Airolo it is necessary to line the gallery and arch the roof with masonry.

ORDNANCE AND NAVAL.

THE NEW RIFLED MUZZLE-LOADING 9-INCH ARMSTRONG GUN AT SHOEBURYNESS. A series of experimental trials with a new rifled muzzle-loading wrought iron and steel coiled gun, having an actual calibre of 8.8 in., which has recently been manufactured at the works of Sir William Armstrong and Co., at Elswick, is about to be made under the superintendence of the Commandant of the School of Gunnery at Shoeburyness. This piece of ordnance is of a most interesting character, as it has been designed with a view of combining most of the advantages of the breech-loading system with all the simplicity of an ordinary muzzle-loading gun. In appearance it very much resembles both as to contour and dimensions a 9 in. Woolwich gun of the Fraser construction. The rifling is polygrooved, with an increasing spiral terminating in a tolerably sharp curve.

Both gun and projectile are so contrived as to prevent, so far as is possible, the occurrence of scoring, and to secure, as closely as it can be attained, perfect centring of the one within the bore of the other. These two considerations are of the highest importance. The action and effects of scoring are well known. At first it merely roughens the inner surface of the steel tube, but by degrees it eats away the metal until at length deep furrows and ridges are made which necessitate the condemnation of the gun. The origin of this action is the rush of powder gas over the body of the projectile, the truth of such theory being clearly demonstrated by the fact that the deepest scoring takes place upon the upper surface of the tube, the shot or shell, owing to its own gravita-

tion, lying, of course, upon the lower surface, and consequently admitting of greater windage above than below. The action and effects of indifferent centring are discussed at full length in an article upon "Mechanical Forces in Heavy Ordnance," to be found in "Naval Science" for the past quarter. There it is shown that some at least of the exceptional pressures which presumably cracked the tube of the original 35-ton gun were due to this cause, as they originated in a great measure in the tremendous friction of the projectile when forcing its way out of the bore, such friction being the result of bad centring, for in all cases with Woolwich guns, when the projectile rests in its normal position at the bottom of the bore, it is supported only at two points near the centre—namely, the lower front and rear studs—thus leaving considerable windage above it. When the forces of the powder gas wave press upon its upper surface, because the portion behind the rear studs is of greater superficial extent than that beyond the front studs, more power is exerted upon the base than upon the point, and the latter is consequently tipped up, throwing the projectile obliquely across the bore of the gun. In point of fact, it is partly with the idea of giving more support to the shot or shell, and so preventing the continual "knockings' upon the bore by the oblique action produced, that a third ring of studs has been added to the projectiles for the 35-ton gun.

As before said, the gun and projectile now under consideration are intended to obviate all these difficulties. Rotation of the latter is effected by means of a soft metal ring, which is driven on to a coned portion of its base, and which is forced by the shock of discharge into the space between the surface of the projectile and the grooves. This at the same time entirely closes all windage, so as to check the action of the powder gas, and preclude any possibility of scoring, whilst the projectile centres itself truly in the bore, from the tendency of the soft metal ring to squeeze in evenly all around it. The cone is fluted with rectangular recesses, cut deeply into the material of which the shot or shell is manufactured. These recesses cause the ring to grip tightly when it is driven home by the explosion, and prevent the shot passing out of the bore without obtaining a due amount of rotation.

The projectiles, which have already been despatched to Shoeburyness for use with the 8.8 in.-gun from Elswick, consist of common and chilled shells. They approximate closely in length and weight to those for the 10 in. Woolwich gun of the Fraser construction of 18 tons. No coating of soft metal has been superimposed upon them, as it would not of course be possible to ram them home if the coating fitted tight, and otherwise it would be of no avail. But in the several preliminary trials which were made with this gun and its projectiles in the works of Sir William Armstrong and Co. it was found that rotation was very satisfactorily accomplished, whilst the desired end—viz., absence of windage and correctness of centring—was attained to a very considerable extent; hence there would appear to be no necessity for any additional "coating" or guiding medium. The proposed series of experiments is undertaken with a view of trying the new gun at long ranges, and should their result be as favorable as that of the earlier ones at short ranges, it is exceedingly probable that the manufacture of a number of such pieces of ordnance will be undertaken forthwith. The idea has at least the merit of considerable ingenuity. We need hardly say that soft metal rings have been used to impart rotation to projectiles before, but the precise modification proposed by the Elswick firm in the present instance is, we fancy, entirely novel, and possesses many original points of advantage.—*Engineer.*

ON THE SCREW RUDDER.—By V. Lutschaunig, Esq., Professor of Naval Architecture at the Royal Academy of Trieste, Member. The idea of swiveling the propeller of a ship, in order to make it serve also for the purpose of steering, dates as far back as the year 1862; but so great are the difficulties connected with its practical execution, that an application to large vessels becomes utterly impracticable. It must, indeed, appear at first sight that it would be extremely imprudent to hang a mechanism of such vital importance as the propeller of a ship on a movable joint, and to transfer the thrust-bearings to inaccessible positions outside the vessel. The steering contrivance which I now propose, surmounts all these difficulties in a very simple manner. The main or driving propeller of the vessel remains perfectly unaltered, and a small swivelling screw, just of sufficient size to answer the steering purposes, is fitted abaft it, precisely in the centre of the rudder-blade itself, where by the nature of its action, which is always identical with that of the rudder, it greatly contributes to increase the steering power. The shaft of the steering screw turns round the vertical axis of the pintles, or in a balance rudder round the corresponding rudder axis. I have, however, only taken the latter form of rudder into consideration, in the way of adopting steering screws to ships already existing—for with my contrivance balance rudders become perfectly superfluous—and I consider a usual rudder capable of being shipped and unshipped together with the steering screw in the old-fashioned manner preferable under all respects.

In the model which I have constructed, the joint at the pintles is formed by three bevel wheels. I have found that the use of such wheels for similar purposes answers very well. On a crane pontoon, driven by a small swivelling screw, which has been in constant use for eight or nine years in the Arsenal of Pola, these mechanisms work to great satisfaction. Arranged in this manner, the steering screw revolves in the opposite direction to that of the driving screw, so that the two propellers must of necessity be right and left handed. The bending back of the blades of the steering screw has been done with the view of preventing the whirl of water which it produces from coming into contact with the main propeller.

As for the principal advantages which this steering contrivance affords, they may be summed up as follows: 1st.—Great increase of steering power, produced by the combined action of the steering screw and the rudder blade. 2d.—The possibility of turning the vessel from her position of rest with the first revolutions of the engines. 3d.—Nearly equal facility in steering when going astern as when going ahead. It is well known that the steering of screw ships when they are

going astern is very uncertain. 4th.—A partial elimination of the tendency of steering better one way than the other. This will be in consequence of the two screws revolving in opposite directions. 5th.—When the ship is under canvas the screw rudder acts precisely as the usual one. If desired it can, however, be also disconnected by a slight suspension of the whole steering apparatus. 6th.—The rudder may be shipped and unshipped while the vessel is afloat. 7th.—Screw rudders might eventually be even kept on board as fighting rudders, keeping a plain rudder in place for ordinary navigation.—*Discussion.* Mr. J. Scott Russell was not sure that for very small war-ships wanted to manœuvre with enormous rapidity, he would not be tempted to try this form of rudder. Mr. Curtis' plan had been tried under the auspices of the Admiralty, and he understood had answered tolerably well. It had not been introduced, for there were probably difficulties in the way, and on a very large scale the difficulties would, he was afraid, become very great. There was a good deal of elegance in the idea, but whether it was worth the trouble was another question. On the whole, the problem was a pretty one, and so was the solution; but he did not like the toothed wheels. In a small vessel, however, he saw no difficulty in putting the whole screw into the rudder. Mr. C. W. Merrifield pointed out that Mr. Lutschaunig had really successfully put the whole screw into the rudder on a small though somewhat special scale. Mr. Willson referred to a similar adaptation which had been found to work remarkably well on the Erie canal. He thought the steering propeller could be turned to most efficient account on canals, but, if applied to lake or ocean vessels, would prove a failure. Mr. J. Fortescue Hannery said the principle involved in the proposal before the meeting was by no means a new one, and that he should be very apprehensive indeed in fitting such an apparatus to any sea-going ship, even if it proved able to increase the manœuvring power of the vessel. After a few further remarks by Messrs. Willson, Scott, Russell, and Merrifield, the discussion closed.

BOOK NOTICES.

THE CONQUEST OF THE SEA; A BOOK ABOUT DIVERS AND DIVING. By HENRY SIEBE. (London: Chatto and Windus.)

The writer of this book claims for the science of diving a place among the industries of the time, and its claims to such place no one who has read the details of its triumphs here described will refuse to concede. In the construction of bridges and harbors, in clearing away obstructions to navigation, in recovering treasure from the maw of the ocean, the modern diver's services are in extensive requisition. Mr. Siebe's treatise is arranged on an exhaustive plan. He introduces his subject with a disquisition on man's natural and unaided efforts to explore the mysteries and ravish the native treasures of the deep, in which the wonderful feats of the Polynesians, the story of Nicholas the Fish, that of the outwitting of Antony by the Egyptian queen, are repeated, and the pearl, coral, and amber fisheries described. Submarine topography and the instruments employed in it are next referred to, and then follows the more important history of the development of the modern methods, including diving bells, diving ships, and the more perfect system which dispenses with these clumsy adjuncts, and sends down the explorer in a water-proof dress, but otherwise nearly as free in his actions as his collegues on dry land. Mr. Siebe's father was, we believe, among the first to improve the dress or armor, with the aid of which the diver is enabled to dispense with his bell; and the first important operation of this nature ever effected was the destruction of the wreck of the Royal George, under that gentleman's superintendence. We must add that this very interesting book is amply illustrated with well-executed engravings.

A COMPLETE PRACTICAL TREATISE ON THE NATURE AND USE OF LOGARITHMS AND ON PLANE TRIGONOMETRY. By JAMES ELLIOTT, Professor of Mathematics in Queen's College, Liverpool. Fifth Edition. (Edinburgh and London: Thomas Laurie.)

In this text-book we have a companion volume to the author's "Complete Treatise on Practical Geometry and Mensuration," composed on the same plan, and arranged so as to come in proper connection with it. It also is mainly a practical treatise, and with the numerous improvements added in the course of successive editions has been so much enlarged as likewise to claim the qualification of complete. Both works belong to an extensive educational series, the mathematical portion of which is by the same author.

THE YEAR-BOOK OF FACTS IN SCIENCE AND ART. By JOHN TIMBS. (London: Lockwood & Co.) For sale by Van Nostrand. Price $2.

The work, which has now been published under this title for a good many years, consists of a copious selection of the leading facts of the year, condensed and compiled from the usual sources of public information. The information thus communicated is, therefore, neither more nor less exact than the source—chiefly the newspaper press—from which it has been culled. Still there are large classes of readers who desire such information, and to whom it is useful. From a cursory inspection of the present volume, which embraces the past year, we should say that in extent and variety, as well as arrangement, it is fully equal to any of its predecessors. The contents include the useful arts, science, and necrology. The volume is prefaced by a memoir of Prof. Tyndall, whose portrait faces the title-page.—*Iron.*

A POCKET-BOOK OF USEFUL TABLES AND FORMULÆ FOR MARINE ENGINEERS. By FRANK PROCTOR, Associate of the Institute of Naval Architects. (London: Lockwood & Co., 1874.) For sale by Van Nostrand. Price $2.

This moderately-priced, useful, and very complete pocket companion, is prepared for engineers and engine draughtsmen in the royal and mercantile marine, from whom the particulars they specially require are collected into a handy and compact volume for the pocket. The very completeness of the work, however, renders recapitulation difficult; but we may state that scarcely anything required by a naval engineer appears to have been forgotten. At the same time, we would remind

those for whom it is intended, that in order to get the full value out of such a work, the person using it should, in the first instance, make himself thoroughly acquainted with its contents, so that he may at once know where to turn in any difficulty in which it is likely to be of service.

A MANUAL OF THE MECHANICS OF ENGINEERING, AND OF THE CONSTRUCTION OF MACHINES, WITH AN INTRODUCTION TO THE CALCULUS. Designed as a Text-book for Technical Schools and Colleges, and for the use of Engineers, Architects, etc. By Julius Wiesbach, Ph. D., Oberbergrath and Professor at the Royal Mining College at Freiberg; Member of the Imperial Academy of Sciences at St. Petersburgh, etc. Vol. I. Theoretical Mechanics. Translated from the Fourth augmented and improved German edition. By Eckley Coxe, A. M., Mining Engineer. Published by D. Van Nostrand. Price $10.

Our British publishers must be vigilant, and carefully study the demands of modern science, or their American rivals will ere long outstrip them in the race, and provide the English reading races with their best scientific text-books. Brother Jonathan is evidently awakening to the truth that the cultivation of science and its practical applications may be more profitable than the manufacture of wooden nutmegs, and is following up the new "notion" with characteristic energy.

The work before us, published in New York by D. Van Nostrand, is one among many other indications of the scientific awakening of our Transatlantic brethren. It is a well printed and well illustrated volume of 1,112 pages, and the first of the three in which the work will be completed. At the end of the book is a formidable list of technological works published by the same firm. This list is alone sufficient to justify the above reflections.

The volume before us is a thorough and satisfactory exposition of the fundamental principles of mechanical science, treated with especial reference to their practical bearings. The author's principal effort has been to obtain the greatest simplicity in enunciation and demonstration, and to treat all the important laws, in their practical applications, without the aid of the higher mathematics. At the same time he does not agree with those authors who, in popular treatises, enunciate without proof the more difficult laws, but he prefers to deduce or demonstrate them in an elementary, although sometimes in a somewhat roundabout, manner. It is assumed that the reader has a general knowledge of the fundamental principles of natural philosophy, and of elementary pure mathematics, but the use of the Calculus is avoided, the author stating one of his reasons for this, viz., that "it is an undeniable fact that, unless we are constantly making use of it, we soon lose that facility of calculation which is indispensable."

Somewhat inconsistently with this statement, the first part of the work is an "Introduction to the Calculus," where the subject is treated with considerable simplicity and clearness. This is followed by a treatise on "Phoronomics, or the Purely Mathematical Theory of Motion," divided into two chapters; (1) on Simple Motion: (2) Compound Motion. This, with the Introduction to the Calculus, forming the mathematical portion of the volume, occupies the first 153 pages. In the second section, two chapters are devoted to a general outline of Mechanics, defined as "The Physical Science of Motion." This subject is treated more in detail in section 3, wherein are included the General Principles of the Statics of Rigid Bodies; the Theory of the Centre of Gravity; the Equilibrium of Bodies rigidly fastened and supported; the Equilibrium of Funicular Machines; the Resistance of Friction, and the Rigidity of Cordage.

Section 4 is devoted to the Application of Statics to the Elasticity and Strength of Bodies, and treats in detail the Elasticity and Strength of Extension, Compression, Shearing, Flexure, and Twisting, and the Resistance to Crushing by bending or breaking across.

The Dynamics of Rigid Bodies is the subject of the four chapters of Section 5; the Statics and Dynamics of Fluids are treated in sections 6 and 7, which are followed by an Appendix on the Theory of Oscillation.

This slight sketch of the contents of the volume sufficiently indicates its scope and objects. The subjects are conscientiously and well treated, with a sufficient amount of mathematical demonstration for all practical purposes, with rather more, we fear, than will be acceptable to the majority of English practical men, by whom these subjects should be well understood. But we must remember that it is a German work written originally for German engineers and mechanics, who have at the elementary and real-schule received an amount of mathematical preparation that in this country is unfortunately but rarely attained before entering the Universities. Still we have some men in our own country whose education is superior to even the best that any school or college can afford; the men who, in spite of all difficulties, have educated themselves. To such men who have thus mastered the elements of mathematics, and are preparing to take the high technical position to which they are entitled, this work is especially valuable. It supplies them with a mine of worthy study, treated just in the manner and to the extent that such self-taught and self-teaching men demand. We hope it may fall into such good hands, and be well thumbed and studied by many of them.—*Exchange.*

THE MANAGEMENT OF STEEL. By GEORGE EDE, of the Royal Gun Factories Department, Woolwich Arsenal. Fifth Edition. London: William Tweedie. 1873. For sale by Van Nostrand. Price $2.50.

The author of this book is a workman in the strict sense of the word—a craftsman of rare and acknowledged skill and tact in our great national arsenal; and the value of a full and most minute detail of the various nice and delicate manipulations in the forging, annealing, and tempering of steel, the case-hardening of iron, and similar operations, from such a hand, must be at once apparent. The important difference between a scientific manual compiled by a publisher's man-of-all work, and a treatise on the same subject by a skilled and intelligent savan, is well understood in the scientific world. In the sphere of mechanical art, the usual lack of the literary faculty generally proves a sad impediment to a clear exposition of processes by the men best fitted for the task; but this difficulty in Mr. Ede's case has been happily overcome, and

the neophyte in iron-work may here learn the best and most *recherché* secrets of his mystery, as well, if not better, than by sitting at the feet of the hoariest Gamaliel of the school of Tubal Cain. The very homeliness of the style, racy as it is of the forge, will the more commend to it the attention of the apprentices and younger journeymen, for whom the book has been written; while, as far as its scope is concerned, it embraces more or less completely nearly every operation connected with the manufacture of iron and steel, such as the choosing of steel for tools, forging iron and steel, the hardening and tempering of cast iron and steel, the case-hardening of wrought iron, the toughening of mild cast steel for guns, shot, railway bars, etc. The fact that, in a few years, it has reached a fifth edition, is the best proof of the merits of the book; and we understand that one of the most extensive iron and steel manufacturers in France has recently ordered a translation of it for the benefit of the numerous employés of the firm.—*Iron.*

LA CHALEUR; MODE DU MOUVEMENT. Par JOHN TYNDALL, F. R. S. Paris: Gauthier-Villars. For sale by Van Nostrand. Price $3.20.

For readers who desire to become familiar with easy scientific expositions in the French language, nothing could be better than this book. Such treatises have been much inquired for of late.

This translation has been done by an able scientist, and the result of the labor of editor and publisher is an exceedingly inviting volume.

AN ELEMENTARY TREATISE ON MECHANICS. By S. PARKINSON. London: Macmillan & Co. For sale by Van Nostrand.

This clean compact little compend of theoretical mechanics has reached its fifth edition and probably will see many more. It covers the ground of Elementary as completely as possible without the aid of the calculus.

In the place of long dissertations it presents plenty of examples for solution.

THEORY OF ARCHES. By Prof. W. ALLAN. New York: D. Van Nostrand.

No. 11 of Van Nostrand's Science Series. 50c.

This is an expansion of the usual treatment of the arch as given in our higher mechanics.

Such works as this are by no means numerous enough. The illustrations are very abundant, and the treatment exceedingly lucid.

OUR INHERITANCE IN THE GREAT PYRAMID. By PIAZZI SMYTH, F. R. A. S., etc. London: W. Isbister & Co. For sale by Van Nostrand. Price $6.

The first edition of this work appeared about eight years ago, and was followed in a couple of years, 1868, by "Life and Work at the Great Pyramid" in three ponderous octavo volumes.

Much learned discussion was held over Prof. Symth's theories, and the verdict was generally unfavorable. The present edition is enriched by the author's comments upon the views expressed by his opponents. The result, some exceedingly lively reading.

The work is full of instruction; the illustrations are abundant and excellent; and the accuracy of the author's statements unquestionable. Many readers, we might say most, will gladly accept the author's figures and reject the conclusions finally drawn.

We should say, however, that the only opinion that can be properly held regarding some of Prof. Smyth's English sentences is, that they should be rebuilt immediately.

HISTORY OF THE MODERN STYLES OF ARCHITECTURE. By JAS. FERGUSSON, D.C.L. London: John Murray. 1873. For sale by Van Nostrand. Price $12.

Some of our readers will be glad to hear that a second edition of Mr. Fergusson's "History of the Modern Styles" is published. It has not only been revised throughout, but fresh matter has been introduced, with the object of verifying or correcting first impressions regarding buildings commented on. It will afford us materials for an article before long; suffice it at present for us to make known the publication of the volume, and to say that it is a work absolutely indispensable to every architect and architectural student.—*Builder.*

THE UNIVERSE AND THE COMING TRANSITS. By R. A. PROCTOR, F. R. S. London: Longmans, Green & Co. For sale by Van Nostrand. Price $6.

This work is similar to the many of Mr. Proctor's that have preceded it. It is very readable, and none the less so because it contains in the first part the author's theory of the construction or evolution of the stellar and solar systems.

The fullest exposition of the theory of the methods of observation of the coming transit is given in the second part. The illustrations are abundant and excellent.

COMPOUND ENGINES. From the French of A. MALLET. New York: D. Van Nostrand. 50c.

This forms No. 10 of Van Nostrand's Science Series. It gives, in the simplest form consistent with accuracy of statement, the theory of the Compound Engine. Although the device is an old one, the present generation of practical engineers has grown up since the original invention was employed; hence the books and learned articles upon the theory of using the same steam at two different pressures in consecutive strokes, have proved unsatisfactory, inasmuch as the knowledge of the early history of such experiments was assumed.

The sketch of history in this little volume is exceedingly instructive.

VAN NOSTRAND'S MONTHLY RECORD OF SCIENTIFIC LITERATURE. Vols. 1 & 2. Price $1.

Our readers are doubtles all familiar with this convenient catalogue of scientific works. A neat volume is made by the numbers issued from May '72 to April '74.

ESSAYS IN MILITARY BIOGRAPHY. By CHAS. CORNWALLIS CHESNEY, Lieut.-Col. in the Royal Engineers. For sale by Van Nostrand. Price $2.50.

This work has already excited much favorable comment. That an English military writer should give prominent place in a work of this kind to American subjects, is a fact of such note as to draw immediate attention to the book.

Among other essays, the following will, from previous interest in the subjects, be regarded with the most interest on this side of the ocean. Gen'l Grant, Gen'l Lee, Farragut and Porter, Sir Wil-

liam Gordon, Chinese Gordon, and the Taiping Rebellion.

ALLSTON'S SEAMANSHIP. New Edition. By Commander R. H. HARRIS, R. N. With a Treatise on Nautical Surveying, by Staff Commander MAY, F. R. G. S. London. For sale by Van Nostrand. Price $4 50.

The three sections of the first and principal portion of this work are devoted separately to—1. Fitting Out; 2. at Sea; 3. on General Service.

Questions for the guide of the student are afforded in liberal quantity.

The Nautical Surveying receives its due share of space, and is a good supplement to the other sections of the work.

Two hundred diagrams illustrate the text.

A MANUAL OF PUBLIC HEALTH, By W. H. MICHAEL, F. C. S.; W. H. CORFIELD, M. D., and J. A. WANKLYN, M. R. C. S. London: Smith, Elder & Co. For sale by Van Nostrand. $5.25.

This work is designed for the use of officers of the Health Board, and contains valuable hints gathered from experiences in old European cities.

The subjects of drainage, water supply, ventilation, treatment of epidemics, are treated at considerable length, and constantly with reference to the duties of Health Officers.

THE ENGINEER, ARCHITECT, and CONTRACTOR'S POCKET-BOOK, for 1874. London: Lockwood & Co. For sale by Van Nostrand. Price $3.

This is the well known Weale's Pocket Table-Book, which, although containing many things adapted to use only on the other side of the Atlantic, still is so replete with valuable Engineering formulæ that it has long been a favorite table book with many prominent working Engineers.

MISCELLANEOUS.

ELECTRO-STANNUS.—This is a method of "electro-tinning" (as the word implies) articles which it is wished to preserve from rust, or which are to be electro-plated in silver, the tin being the foundation, and thus saving a thick deposit of silver, as well as being scarcely distinguishable from the more valuable metal, even when the electro-plated article has been so far worn as to exhibit the coat beneath. This method is the discovery and invention of Mr. W. E. Tilley, late of Kirby Street, Hatton Garden, and is thus substantially described by him in a patent which he took out in 1869:—

It has hitherto been found difficult to keep in solution the tin contained in the bath, it having a tendency to fall to the bottom in the form of a precipitate. To prevent this, grain tin is dissolved in nitro-muriatic acid, or in nitric acid, and thus a solution of nitro-muriate, or of nitrate of tin, is obtained. To this is added a solution of cyanide of potassium and water, the quantity used being sufficient to precipitate the tin contained in the nitro-muriate, or nitrate solution. The oxide of tin thus obtained is then washed with water in a filter, and either drained or evaporated to dryness, or used when of a pasty consistency. This oxide is then put into an earthenware pan, and as much sulphuric or muriatic acid, or sulphuric and nitric acid, is added as will take up the oxide and hold the tin in solution. A mixture of two parts of muriatic acid to one part of sulphuric acid seems to give the best result. This solution of tin is put into the vat in which the articles to be coated or plated are immersed, and as much soft water added as will make a bath of the ordinary strength used in electro-plating, and which is now ready for use.

To develop this patent, a limited company was formed, and the process carried on for some time in London, but in a very small way. It was soon, however, found that, for obvious reasons, the works would be better at Birmingham; so, extensive premises were purchased in Victoria street, and they are now completely fitted out with sufficient plant to turn out any amount of work.

All kinds of goods have been subjected to this process, such as portions of iron bedsteads, fruit-vases, club skates, letter-box openings, sets of nut-crackers, candlesticks, engraved gun action tablets, sets of keys, cast-iron coffin entablatures, dish covers, etc.; and, from appearance, no one would know but that the articles so subjected were really silver, *pur et simple*. Thus it will be seen that the number of ways in which this invention will be found useful as applied to new articles is almost unlimited. The process can also be applied to "renovate" worn and tarnished goods. Experiments made upon articles completely eaten into by rust, have been eminently successful.

CHANGE OF SHORE-LEVEL NEAR BORDEAUX.—M. Delfortrie says "Les Mondes," had announced in the "Bulletin de l'Association Française" a sufficiently startling fact. "The soil," he said, "of the peninsula of Grave is sinking bodily into the sea in a slow but continuous manner. Whence does this sinking motion date? What will be its limits? No one knowns. . . . . Bordeaux and its territory are fatally devoted to death (*sic*) like the mysterious Atlantis of the ancients: unless the character of the movement of oscillation should change, a day will come when the waves of ocean will cover this rich city and all its vineyards, the source of a flourishing commerce." We found it surprising, adds "Les Mondes," that M. Leverrier's "Bulletin" should have made itself the echo of these terrors, which seemed to us less than justified by the documents adduced in their support. At present a very competent and well-authorized geologist, M. Victor Raulin, after having corrected the greater number of the facts alleged by M. Delfortrie, concludes thus in the "Bulletin" of May 12:—"M. Delfortrie's new ideas of submergence will have the same fate as his former ideas of the elevation of land, unless he bring precise and incontestable facts in support of his theoretical views of 1869 and his diametrically contrary views of 1872. In fact, geologists will not admit without very convincing proofs that phenomena have occurred successively on the shores of La Gironde resembling those which actually occur at the two extremities of Scandinavia, at the extremity of the Gulf of Bothnia, and in Scania. Such a thing is, indeed, not impossible, but it cannot be admitted into science until it has been duly established, which remains to be accomplished."